AN INSURGENCY GROWTH MODEL

Robert Meredith Combs

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN INSURGENCY GROWTH MODEL

by

Robert Meredith Combs

Thesis Advisor: Glen F. Lindsay

An Insurgency Growth Model

by

Robert Meredith Combs
Lieutenant, United States Navy
A. B., University of North Carolina, 1967

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1973

ABSTRACT

A generalized conception of an insurgency situation is examined with a systems approach. The model is divided into two sectors, propaganda and military. The emphasis in the propaganda sector is on all actions taken by the insurgent and government sides which have a psychological impact on the population. In the military sector variables associated with combat and troop replacement are examined. A computer simulation, written in DYNAMO II, is provided and several simulation runs are examined. Suggestions for further research are also included.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. SUMMARY

Past studies which have concentrated on the individual aspects and variables related to an insurgency situation in isolation from one another ignore an important fact about insurgencies which is true of all social and political systems. That fact is that the variables in these systems, including insurgencies, interact on a continuous basis, and the interactions are indispensable to the complete description of an insurgency. The alternative to isolating variables and ignoring important interactions is to model insurgency as a system, with the ultimate goals of including the significant variables of the system and the description of their interaction with each other. This paper has attempted to lay the groundwork for such a model.

The medium used in the construction of this beginning insurgency model was a method of modelling called system dynamics. System dynamics was devised by Professor Jay W. Forrester of M. I. T., as a means of modelling complex social and industrial systems. In an attempt to demonstrate the behavior of the system, as depicted in the insurgency growth model, on a nearly continuous basis, a computer simulation was written for this study. The simulation was written for the DYNAMO compiler, which was written to provide a computer language for time-stepped simulations involving many interacting variables.

The basic insurgency growth model is divided into two sectors: propaganda and military. The population equations (that is, the breakdown of

the total population into insurgent, government, and neutral populations) collectively provide a focal point for all system behavior generated in the propaganda and military sectors. That is, all system behavior ultimately results in some change in the population profile. The segmentation of the population is also the principal indicator of the state of the insurgency system.

The propaganda sector of the model is the more highly aggregated of the two. In this sector, all action of a psychological nature which either the insurgent side or the government side can take is combined in one variable called propaganda effort. Implicit in this variable are programs such as education, civic action, propaganda, and economic controls. The driving force which determines the intensity of the propaganda effort is represented to be each side's perception of the ratio of government citizens to the total population. Probability coefficients are derived in this sector which describe the probability that a citizen aligned with a particular population faction will change his allegiance to some other faction.

The military sector contains combat and troop-level sub-models. The combat sub-model employs Lanchester's equations of combat, written as difference equations, for determining the battle attrition rates for both sides. An insurgent troop level of 1000 men is used as the point of changeover from guerrilla-style warfare to more conventional warfare. During the guerrilla warfare stage, a Lanchester approach for aimed fire is used for the government attrition rate and a Lanchester approach for area fire is

used for the insurgent attrition rate. In the conventional warfare stage, the equations reflect aimed fire for both sides.

The size of the troop force for the insurgents is maintained at a level proportional to the total insurgent population. The proportion is variable and its magnitude is determined in a functional relationship with the insurgent share of the population as the independent variable. Insurgent troop shortages are replaced on an instantaneous basis. Government troop levels are represented as dependent on the size of the insurgent combat force. The government troop additions and replacements are modeled as subject to various training and bureaucratic delays.

The DYNAMO simulation of the insurgency system provides the analyst with many useful indicators of the progress of the insurgency. Many variables can be observed over time which may give a deeper insight into the operation of the insurgency system. Some of the variables suggested for inclusion in the simulation output for each time period are the populations, the percent change in government and insurgent populations, and a running total of government and insurgent troops killed. Other variables which might give some understanding of the procedure established for maintenance of government troop levels are the actual insurgent troop strength, the indicated government troop strength, and the actual government troop strength. The indicated government troop strength is arrived at through a functional relationship with the actual insurgent troop strength. The actual government troop strength, when it is compared with the indicated strength

for a particular time period, reveals the effects of the time delays placed in the system for troop level maintenance.

Computer simulation results were obtained for a variety of initial population allocations. Two initial allocations for the insurgent side were investigated, 1 percent and 5 percent. Government allocations of 20 through 60 percent were used with each of the insurgent allocations. Generally, the system behavior observed was the same for all initial population profiles. There was an initial period of growth in both the insurgent and government populations, attributable to propaganda effects on the neutral population. The troop levels and combat activity were low during this growth period. Maximum population for insurgents and government are reached at about 31 and 55 percent of the total, respectively. Combat activity becomes predominant at this point and a general decline in the government faction is observed. When the government population declines to about 41 percent of the total population and the insurgent population reaches its maximum of 31 percent, the system settles down to one of relatively little activity. That is, the rate of change in the insurgent and government populations is very slow. This type of activity continues until the end of the simulation run. The only difference noted in the behavior of the system for differing initial population profiles was the speed with which the system attained the various stages of activity just described. The rapidity with which the three stages of activity (growth, decline, abatement) were observed grew with the initial size of the government population. The general trend of behavior was, however, the same in all cases.

II. INTRODUCTION

The purpose of the work reported in this paper was to study a generalized conception of an insurgency situation from a highly aggregated point of view. Many studies have been conducted and models constructed to investigate specific areas of insurgencies, but apparently no effort has been made to quantitatively study the complete insurgency system. The fundamental premise of this study is that an insurgency can be represented as a bounded system within which all behavior peculiar to an insurgency is generated. It remains, then, to determine what variables are included in this system, how they behave, and how they interact with one another.

The model constructed for this study supposes that an insurgency can be segmented into two sectors: one called psychological and one called military. This formulation recognizes that an insurgency is, in essence, a contest between two forces for control of the population of a country or an area of a country. In this contest, the insurgent force and the force in power (the government force) have two avenues of action open to them.

The first of these two courses of action is an attempt to win the population through psychological appeals. This form of action encompasses a wide range of possibilities for the accomplishment of goals. Some of the methods by which either side might seek to accomplish its objectives in the psychological area are: education, community services, civic action, propaganda, and economic controls. In the insurgency growth model, all of these factors are combined into one variable called propaganda.

The second type of action the government or insurgent force can take in order to gain power over the population is military. While psychological action is pursued primarily for the purpose of winning over that portion of the population which is uncommitted, that is the neutral population, military action is exercised by the two opposing forces against one another directly. The goal of either force when taking military action is to gain or preserve power by eliminating the opposing force. The military sector of an insurgency, therefore, is presumed to be concerned with combat.

This systems appraoch to insurgency is worthwhile, because once a reasonable representation of the insurgency as a whole is achieved, one is able to view all the implications of a proposed plan or action simultaneously. Isolated studies such as a cost-effectiveness study of a civic action program or the evaluation of intelligence collection efforts are worthwhile but their value increases greatly when one can view them in the context of the entire system. Further, the systems approach allows the analyst to conduct sensitivity analysis for the purpose of determining those factors in the system which are most critical and therefore deserve the most attention in research.

In this study, a model was constructed using the simplifications and structure already outlined. A computer simulation was used to analyze numerical results from the model. The computer simulation allows the variables of the model to interact on a nearly continuous basis.

The model is described in Chapter III, and the simulation is presented in Chapter IV. Chapter V is devoted to a description of the assumptions

used in the model and an analysis of the rationale for those assumptions. In Chapter VI, several indicators are suggested as useful in describing the state of the insurgency as it is portrayed in this model. Also, Chapter VI will analyze simulation runs to give further insight into the workings of the model. Chapter VII contains conclusions and several suggestions for expansion of the insurgency growth model.

III. MODEL DESCRIPTION

An insurgency situation is described by a myriad of variables, as is any complex political or social system. One of the aims of this paper is to reduce the insurgency situation to a manageable number of variables. Another goal of this project is to describe the interactions among the various elements of insurgencies. This second goal is approached through the use of the "system dynamics" method of modelling complex social and industrial systems, attributable to Professor Jay W. Forrester of M. I. T. [4]

An overview of the system dynamics method is presented here. The hierarchy in system structure, according to Forrester, is summarized as follows:

Closed Boundary

Feedback Loop Structure

Level and Rate Substructure.

The closed boundary concept defines a boundary which contains the system of interest and states that the behavior characteristic of that system is created entirely within the boundary. Outside occurences may affect the system but must be viewed as disturbances for the excitation of the system. The feedback loop structure is really the essential element of the system. This loop is a path in the model linking decision, action, level (or state) of the system, and information about the system. The level and rate variables provide the foundation for the feedback loop. The level variables

describe the condition of the system at any time, and the rate variables determine the rate of change of the level variables. This heirarchy provides the means by which one may show, through the actions (or rate variables), all the interrelationships of the elements of his model.

In this insurgency model the closed boundary describes a hypothetical population split between pro-government, neutral, and insurgent factions. Unlike the Forrester structure, the model is divided into two sectors: propaganda (or psychological) and military. The levels and rates within each of these sectors and their relationship to each other describe the insurgency system. Both of these sectors determine the rates for the generation and attrition processes for each of the three factions of the population as well as total population.

A computer simulation was written for the model in DYNAMO II. The simulation will be discussed in detail in Chapters IV and V, but it is necessary at this point to understand the time orientation of the simulation in order to follow the rationale behind the equations of the model.

DYNAMO II is designed for time-stepped simulations. Once the user determines the smallest time frame of interest, he must tailor all the equations of his model to that time frame. The basic time unit selected for the insurgency growth model was one month, so, the output of the simulation in one itteration may be viewed as the result of one month's activity in the insurgency system. For example, the insurgent troop attrition rate for one time period in the simulation is the result of one month of combat between insurgent and government troops.

A. PROPAGANDA SECTOR

The two most important levels contained in the propaganda sector are those called insurgent propaganda effort and government propaganda effort. These levels are an aggregation of all possible actions the government and insurgent sides can take other than those of a purely military nature. Included in the range of these variables are actions such as education, community services, civic action programs, propaganda, and economic controls.

The intensity of the propaganda effort for both the insurgent and government sides is determined by an equation of the form:

$$\text{EFFORT} = \alpha \cdot (\text{Desired effort this time period}) + (1 - \alpha) \cdot (\text{Actual effort last time period}), \text{ where } 0 \le \alpha \le 1.$$

This equation allows the propaganda decision-maker to base his present allocation of effort not only on the present indicators but on past trends as well. Desired propaganda effort is determined from a functional relationship for each side. The independent variable for this relationship is each side's perception of the ratio of government citizens to the total population. This perceived ratio is determined through the use of an intelligence coefficient for each side. The propaganda effort is scaled from zero to ten for simplicity. This variable can be interpreted in terms of money, manpower, or a quantity which embodies both. It is recognized that the zero to ten scale is meaningless by itself, but is useful in a relative sense for obtaining the important quantities of the propaganda sector, called "propaganda probability coefficients."

The probability coefficients correspond to actual probabilities of certain events taking place in a time period. They are used in the population rate equations to determine population attrition and generation. There are six probabilities from propaganda (corresponding to six possible events):

1. The probability a neutral citizen changes allegiance to insurgent.
2. The probability a government citizen changes allegiance to insurgent.
3. The probability a government citizen changes allegiance to neutral.
4. The probability an insurgent changes allegiance to neutral.
5. The probability an insurgent changes allegiance to government.
6. The probability a neutral citizen changes allegiance to government.

The probabilities are computed from equations of the form:

P(x to y) = P(insurgents or govt. reaches a citizen)

• P(citizen reached is x)

• P(ins. or govt. propaganda makes x change to y).

The probability that insurgent-government propaganda "reaches" a citizen is found in a functional relationship for which the independent variable is insurgent (or government) propaganda intensity. The probability that a citizen will be x is simply the ratio of x citizens to the total population. The probability that the insurgent-government propaganda is favorable enough on x citizens to make them change their allegiance to the y population is computed in one of six relationships (corresponding to the six possible events previously listed) where the independent variable is insurgent-government propaganda intensity. Once these probabilities are obtained, they are used in the appropriate population rate equation. For

instance, the probability that an insurgent converts to the government side (PMIG) would be used in the government population generation rate equation in the following manner,

Govt. Generation Rate

$$= \ldots + \text{PMIG} \cdot (\text{Present No. of insurgents}) + \ldots$$

B. THE MILITARY SECTOR

The military sector of this model is concerned with two related problems: combat and troop replacement. The important levels of this sector are the troop levels: insurgent, government police, and government regulars. They, almost as much as the population profiles, serve to describe the progress of the insurgency. The number of insurgent troops, for instance, includes not just combat troops but the number of full-time, hard-core insurgents present in the system. This number contrasted with the total insurgent population (which might include everyone from sympathizer to full-time soldier) could give one some insight relative to the "seriousness" of the insurgency. Additionally, if the number of troops on both sides increases, the combat model takes on more of the characteristics of conventional warfare, which certainly has major implications for the conduct of counter-insurgency operations.

C. THE COMBAT MODEL

The means of determining the number of government and insurgent troops killed in a time period is through an insurgent warfare modification of Fredrick W. Lanchester's equations of combat.

Battlefield attrition equations should provide for two distinct types of combat. First, in the initial stages of insurgency, when insurgent strength is low, the insurgent group is quite likely to devote relatively few of its number to combat duties. At this point, the insurgents are more interested in propaganda and broadening their base of support. Consequently, when their force is small, the insurgents will probably be unwilling to engage the government forces in combat. Also, when combat does occur, the insurgents should have the advantage of fighting on their own terrain, and many times, on their own terms. Equations for this type of combat should reflect government difficulty in bringing the insurgents to battle as well as the likely government disadvantage when combat does occur.

The second type of combat situation becomes apparent when the insurgent force grows larger. The insurgents now begin to shift their emphasis to military operations in an attempt to defeat the government decisively. As this phase in the insurgency develops, combat begins to resemble conventional warfare with increasing frequency of contact, larger forces involved in combat during any given contact, and more of an advantage to the force which has better equipment (presumably the government with aircraft, tanks, etc.).

With this second variety of combat in mind, then, we wish to write the equations in such a way that they reflect the shift in emphasis by the insurgent group and the ensuing changes in the combat situation. S. J. Deitchman [3] adapted Lanchester's equations for use in the analysis of

guerrilla warfare. His resulting equations for government and insurgent attrition rates are:

$$dGovt./dt = -\alpha \cdot (\text{no. insurgent troops})$$

$$dIns./dt = -\beta \cdot (\text{no govt. troops}) \cdot (\text{no. ins. troops}).$$

The equation for the government attrition rate employs the Lanchester form for aimed fire. The equation for insurgent attrition rate, on the other hand, utilizes the Lanchester form for area fire. Although different dimensionally, the constants α and β can be viewed as "weapons effectiveness coefficients."

Deitchman gives the advantage of ambush to the insurgent group in these equations. This may not be true for all insurgency situations. More important than the conceptual basis for the equations, however, is the behavior of the equations. By using Deitchman's equations and judiciously choosing β (government weapons effectiveness) one can represent the difficulty government forces have historically experienced in achieving significant military results against small insurgent forces. That is, in the equation for insurgent attrition rate, one can see that as the insurgent force grows smaller, fewer insurgents are killed per unit time. If one views this arrangement as a reflection of the unwillingness of small insurgent groups to engage in combat, rather than in the insurgent ambush vs. conventional warfare context, a reasonable representation of combat in the beginning stages of an insurgency is achieved.

As the insurgent group grows, of course, the size of its military force increases as does the desire for combat. It would follow also, that with

these larger forces and the increased frequency of contact, combat begins to take on more of the characteristics of conventional warfare. This phenomenon requires that the model first have a criterion for determining when this shift in combat emphasis occurs, and second that the model must be able to reflect that shift in its equations for attrition.

In this insurgency model the first requirement, a criterion for determining when combat begins to shift toward conventional warfare, is satisfied by setting a level of insurgent troop strength (1000 in this case) as the beginning of the shift in combat emphasis. As this point, a number of changes take place in the input to the attrition equations. These changes can be described by contrasting the values the attrition equation variables take on during the time that the insurgent force is considered "small" and after the insurgent force has gained sufficient strength to begin conducting more conventional combat operations.

The government and insurgent attrition rate equations appear in the model as difference equations,

$$DG = FCI \cdot TTI$$

$$DI = FCG \cdot TTG \cdot IC,$$

where DG and DI represent government and insurgent troops killed per time period. The variables FCI and FCG are, respectively, the "fighting constants" for insurgent and government troops and serve the same role as Lanchester attrition coefficients. The total number of insurgent troops involved in combat during the present time period is represented by TTI,

and TTG is the corresponding variable for government troops. The variable IC is equal to TTI when the insurgent force strength is below that required by the model for the shift to more conventional warfare. After the insurgent force reaches the required strength IC becomes a constant equal to 1000.

Prior to the shift to conventional combat, the equations for DG and DI are just as previously described. That is, the equation for government attrition employs Lanchester's form reflecting aimed fire for the insurgents, and the insurgent attrition rate uses Lanchester's form for area fire. To achieve a reasonable representation of the early stages of combat, the fighting constants are fixed at 0.1 for the insurgent force and 0.0001 for the government force. When combat shifts toward conventional warfare FCI increases linearly to a maximum of 0.2. At the same time, FCG increases linearly to 0.0002, but FCG reaches its maximum more rapidly than FCI. Since once the shift occurs IC assumes a constant value of 1000, the effect is to attrit both the government and insurgent forces using Lanchester's form for aimed fire, with the government fighting constant assuming the same order of magnitude as the insurgent fighting constant. The difference between the rates of increase for the government and insurgent fighting constants gives an initial "equipment" advantage to the government forces when they begin to fight something resembling a conventional war.

The variables for total troops involved in combat are also computed in two ways, depending on the phase of combat. When combat is in the initial phase, the total troops involved for both sides is simply set at the

total number of soldiers each side has (or any multiple). After the shift toward conventional warfare occurs, a table is entered each time period to find the expected number of encounters between government and insurgent forces. The independent variable for this table is the total number of insurgent troops. Another table is entered at the same time to find the expected force size for both sides. The quantities obtained by multiplying expected force size by the expected number of encounters are the total troops involved per time period for both sides.

The combat submodel, in summary, passes through two stages. The first stage can be described as guerrilla warfare. In this phase, the government forces have a difficult time locating and bringing the small insurgent force to combat. Consequently, the insurgent force undergoes a very small attrition rate during this phase. As the number of insurgents grows, the model begins to shift toward more conventional warfare. The attrition rate is computed under the same rules for both sides and the advantage for the government of better equipment becomes apparent. Combat attrition for both sides is established always by the same two equations. Government forces, both policy and regulars, are to be attrited separately. This is accomplished by simply multiplying the government attrition rate in a time period by the fraction of police and regulars present in the system in that time period.

D. TROOP GENERATION AND REPLACEMENT MODEL

The model uses the beginning levels of total population and insurgent population to generate initial forces for both the insurgents and the

government. The decision rule for the insurgents is represented by finding a percentage of their total strength which they desire to devote to combat. This percentage depends on the current ratio of insurgents to the total population. Generally, the fraction of insurgent strength allocated to troops will be small when this ratio is small and relatively large as the ratio becomes large.

The initial assignment of government forces is found in a functional relationship which depends on the government intelligence estimate of insurgent troop strength. As a rule, this relationship will attempt to maintain relatively high ratios of government troops to insurgent troops when insurgent strength is low and, as insurgent strength grows, this ratio will apprach one. Additionally, as input to the model, the user must specify what portion to the total government strength is to be devoted to police. This is done by specifying the desired ratio of police to the total population. The model then determines how many police are needed, and the government regulars make up the difference.

As the insurgency progresses, the means used to determine the initial government and insurgent troop requirements becomes a procedure for setting "goals" for each successive time period. That is, for each time period, insurgent troop strength is estimated by the government, and the insurgents' share of the population is determined by the insurgent group. The quantities obtained from the relationships for insurgents and the government become the desired troop levels for the next time period.

In the case of the insurgents, the portion of the total strength to be devoted to troops is obtained and the required number is added to the force in the next time period. If the actual number of troops is greater than that required, those "extras" are disposed of by attrition. This process is, in essence, recruitment directly from the insurgent population. Thus, the allowable size of the insurgent force is directly dependent on two things: insurgent share of the total population and total insurgent strength. However, both of these quantities depend on the effectiveness of the insurgents' propaganda campaign, or the number of people they are able to recruit.

The government group has two categories in which to maintain troop levels: police and regulars. The category of "police" as it is used here may be interpreted to include both police forces and local militia. This force is obtained entirely from the population. Replacement is called for when the number of police falls below the prescribed ratio with the population, and any excess is allowed to diminish through combat attrition. There is also a "training" delay for police replacement.

The government is allowed to generate additional troops and replace regular troops lost through combat attrition from outside the system. In this model, the government does no recruiting directly from the local population. Since the government desires to use its resources most efficiently, however, it is faced with the additional problem of removing soldiers from the system when the number of regulars present exceeds the number required.

So, in each time period, the government determines the difference between existing regulars and that number required by the present level of insurgent strength. If the difference shows that more regulars are required, that number is added after a delay attributable to training and a decision-making process. This delay not only holds up the entire requested reinforcement but allows the troops to arrive in the system only a few at a time. This procedure provides an element of realism in that the government is in a constant "hunting" process in an attempt to satisfy a troop level goal about which it never has completely accurate information.

For the task of removing troops which are in excess of those desired, the government group has a similar problem. The difference here is that a lower limit is set on the number of government regulars to be scheduled for removal in any time period. This provides for government recognition that their allocation system is not precise and that an error in the direction of too many troops is better than leaving too few in the system. Once the decision has been made to remove regular troops from the system, a delay of the type characteristic of troop replacement is experienced.

The military sector of the model that we have described contains a process of attrition and replacement of not only the insurgent and government forces but, through the insurgent and police forces, attrition of the total population as well. The combat attrition sub-model uses Lanchester's equations of combat in two modes: traditional guerrilla warfare and conventional warfare. Troop replacement for the insurgent group is described

as a relatively simple process of recruitment from the existing insurgent population, with their requirements being determined by their success in converting the population through propaganda. Government troop replacement, on the other hand, is structured as a rather complex process with bureaucratic and training delays as well as decision-making based on incomplete or incorrect information.

The output from the propaganda and military sectors comes together to provide the basis for the population rate equations. These rate equations, in turn, determine the population levels; total, neutral, insurgent, and government; for each time period. Table I shows the contributors to each rate for the population levels of interest.

TABLE I

Generation and Attrition Factors for Population Levels

Total Population Generation	Attrition
none	1. insurgent combat attrition 2. police combat attrition rate
Neutral Population Generation	**Attrition**
1. propaganda conversion insurgent to neutral 2. propaganda conversion government to neutral	1. propaganda conversion neutral to insurgent 2. propaganda conversion neutral to government
Insurgent Population Generation	**Attrition**
1. propaganda conversion neutral to insurgent 2. propaganda conversion government to insurgent	1. propaganda conversion insurgent to neutral 2. propaganda conversion insurgent to government 3. insurgent combat attrition rate
Government Population Generation	**Attrition**
1. propaganda conversion neutral neutral to government 2. propaganda conversion insurgent to government	1. propaganda conversion government to neutral 2. propaganda conversion government to insurgent 3. police combat attrition rate.

IV. DESCRIPTION OF THE COMPUTER SIMULATION

A computer simulation was written for this study in DYNAMO II for the IBM 360-67 computer. The DYNAMO II compiler was designed by the Industrial Dynamics Group at the Sloan School of Management, Massachusetts Institute of Technology, to provide a computer language to complement the system dynamics method of modeling. A complete description of DYNAMO II is found in the DYNAMO II User's Manual [5]. The simulation, therefore, is structured in much the same manner as the model which was described in Chapter III.

The simulation advances in one-month time steps for as many months as the analyst desires. Through a system of time subscripting unique to DYNAMO II, the levels, which describe the state of the insurgency, are computed at the beginning of each one month time period, using rates computed with inputs from the previous time period. For example, the present insurgent generation rate to and subtracting the insurgent attrition rate from insurgent population level in the previous time period. The insurgent generation and attrition rates would have been computed during the previous time period.

There are four types of equations used in the simulation: level, rate, auxiliary, and initial value. A level equation was just described in an example of the DYNAMO time procedures as they apply to this simulation. The important level equations in the simulation are total population,

insurgent population, government population, neutral population, government troop level (regulars), government troop level (police), and insurgent troop level.

There are two rate equations associated with each of the important level equations mentioned above. One rate equation depicts growth in a particular level and the other depicts attrition or reduction in size. Just as in the level equations, new rates computed in each time period are retained by the DYNAMO compiler for use in computing present level values.

Auxiliary equations are used principally to provide input for the rate equations. They are always computed for the present time period, using input from the present time period. An example of an auxiliary equation is provided by the computation of the probability of an insurgent's conversion to neutral status by propaganda. This probability is the product of the present values for the probability that the government reaches a citizen with propaganda, the probability that the citizen is an insurgent, and the probability of converting an insurgent to neutral with propaganda. The resulting value is then used as a propaganda coefficient in the insurgent attrition rate and neutral citizen generation rate equations.

Included in the topic of auxiliary equations are three special DYNAMO function types used in the simulation. These functions are the tabular function, noise function, and delay function. The table function is a table look-up routine for which the argument is present value of some system variable (i.e. levels or auxiliaries). It is in these tables that most of the critical assumptions of the model, and therefore the simulation,

are contained. Since the individual tables will be discussed in detail in Chapter V, it is important to note only a few characteristics of the tabular function here. The independent variable for the table and its range of values are set forth in an auxiliary equation. A "table" expression follows this auxiliary equation. This expression provides values of the dependent variable at specified intervals. The program uses linear interpolation to arrive at values between the provided coordinates.

The noise function is used for the generation of random numbers, which are uniformly distributed between -1/2 and +1/2. This function can be modified by a linear transformation to broaden or narrow the range of numbers generated and is most useful when used as a coefficient to reflect the effectiveness of military intelligence. For example, an intelligence coefficient of this type is used to compute both the insurgent and government evaluation of enemy strength.

The third special DYNAMO function used in the simulation is the delay function. There are two types of delay functions used in DYNAMO. The first simply holds up the delivery of information to the decision-making process or material to the system by a user-specified number of time periods. An example of this type of delay is provided by the delay brought on by the need to train troops before using them as replacements. After the specified delay all the material or information is allowed to reach its destination at once.

The second type of delay used also stops delivery of information or material for a specified number of time periods. In addition, this delay,

after the waiting period has passed, allows only a portion of the information or material to arrive during succeeding time periods. That is, after waiting the required time, the information or material is allowed to only trickle into the system.

The initial value equations occur in three forms. Some initial values are provided as numerical input by the user. Equations are also written for initial values of certain variables, using constants and the initial values of other variables as input. Many initial values in the simulation are computed automatically by the DYNAMO compiler.

For this study the program written is composed of the four major equation types and the functions discussed above and is constructed around three major parts: population, propaganda, and military. The population segment of the program is composed of level equations which describe the division of the population among the government, insurgent, and neutral factions as well as the size of the total population in any time period. The rate equations associated with each of the population levels are included in this segment also.

In the propaganda sector the levels of interest are those which describe the current propaganda effort for both the government and insurgent groups. These levels are used in the functional relationships of the propaganda sector to provide input to the relationships which compute the propaganda probability coefficients (i.e. the probability that a citizen switches his allegiance from one population faction to another). These coefficients are,

in turn, used in the population rate equations. The propaganda effort levels are computed from auxiliary equations.

The military sector contains the equations for combat as well as those for troop replacement. Government troops (regular), government troops (police), and insurgent troops are the important levels in this sector. There are also levels for total insurgent troops killed and total government troops killed, but these are only for scorekeeping purposes.

V. ASSUMPTIONS AND RATIONALE

The insurgency growth model was discussed in general terms in Chapter III. Chapter IV provided an explanation of the DYNAMO equations and functions used in the simulation written for this study. The basic structure of the simulation was also discussed in Chapter IV. This chapter provides a detailed description of the assumptions employed in the simulation. The organization of this chapter will be based on the framework of the computer program. That is, there will be three major areas for discussion: Population equations, propaganda sector, and military sector. Much of the material that follows will be couched in terms of the DYNAMO equations and functions used in the simulation. Therefore, some review of the material in the previous two chapters will be implicit in the presentation of this chapter.

The first section of the simulation concerns population and contains the most important levels in the model. The profile resulting from the breakdown of the population among the three factions; government, neutral, and insurgent; yields a revealing statement about the state of the insurgency at any time. Also, the values that the three levels for population take on largely determine the behavior of the system. The initial values which must be supplied to this section are total population, insurgent population, and government population. These values are entirely arbitrary. The attrition and generation rate equations associated with each population level

depend on the coefficients for propaganda effectiveness which are generated in the propaganda sector and the population attrition terms found in the military sector.

In Chapter III, it can be seen that the propaganda effort for both the insurgent and government sides was scaled from zero to ten. It is clear that for interpretation, the propaganda effort should probably be expressed in terms such as manpower or money. However, the relationships of the model are stated, in a relative sense, so that the zero to ten scaling is useful.

The propaganda effort decision rule for both sides makes use of the exponential smoothing technique. If we let E_i be the actual propaganda effort i months ago and let I_i be the indicated effort ("indicated" in the sense of a current system goal) i months ago, then the decision equation for either side takes the form,

$$\text{NEW EFFORT} = \alpha I_0 + (1 - \alpha) E_1 ,$$

where $0 < \alpha \leq 1$. By substitution this equation becomes

$$\text{NEW EFFORT} = \alpha I_0 + \alpha(1 - \alpha) I_1 + \alpha (1 - \alpha)^2 I_2 + \cdots .$$

Thus, it is apparent that our assumption is that the insurgent and government decision-makers rely on both the present indicated effort and the past trend to determine the actual effort to be devoted to propaganda in the present time period. The coefficient for either side must be chosen by the

user to be representative of the system under study. Clearly, the larger α becomes, the more responsive the system becomes to the indicated effort, and consequently, to random fluctuations in the system. As a general rule $\alpha = 0.1$ provides a satisfactory compromise between a system that is too stable and thus fails to follow changes in the real system and a system that fluctuates wildly with immediate indicators [2].

The term indicated effort was mentioned above in the context of a demand made or a goal set by the system in the present time period. This is really what indicated effort is, and is established for each side by a functional relationship (Figures 1 and 2). The independent variables for the insurgent and government indicated effort functions are the insurgent and government perceptions, respectively, of the ratio of government population to the total population. These perceived ratios are arrived at through a uniformally distributed intelligence proportionality coefficient for each side to the actual ratio. These intelligence coefficients reflect the possible percentage error by either side in estimating the ratio of government population to the total population. The range of this coefficient for the insurgent group is -1.1 to -0.1 and for the government side the range is -0.2 to 0.2, giving the advantage of better intelligence to the insurgents. This seems to be a reasonable approach since the insurgents have the initiative in recruiting from the population and are generally better organized at the local level than the government.

Both of the indicated propaganda effort functions in Figures 1 and 2 are based on an intuitive idea of what the emphasis on propaganda might

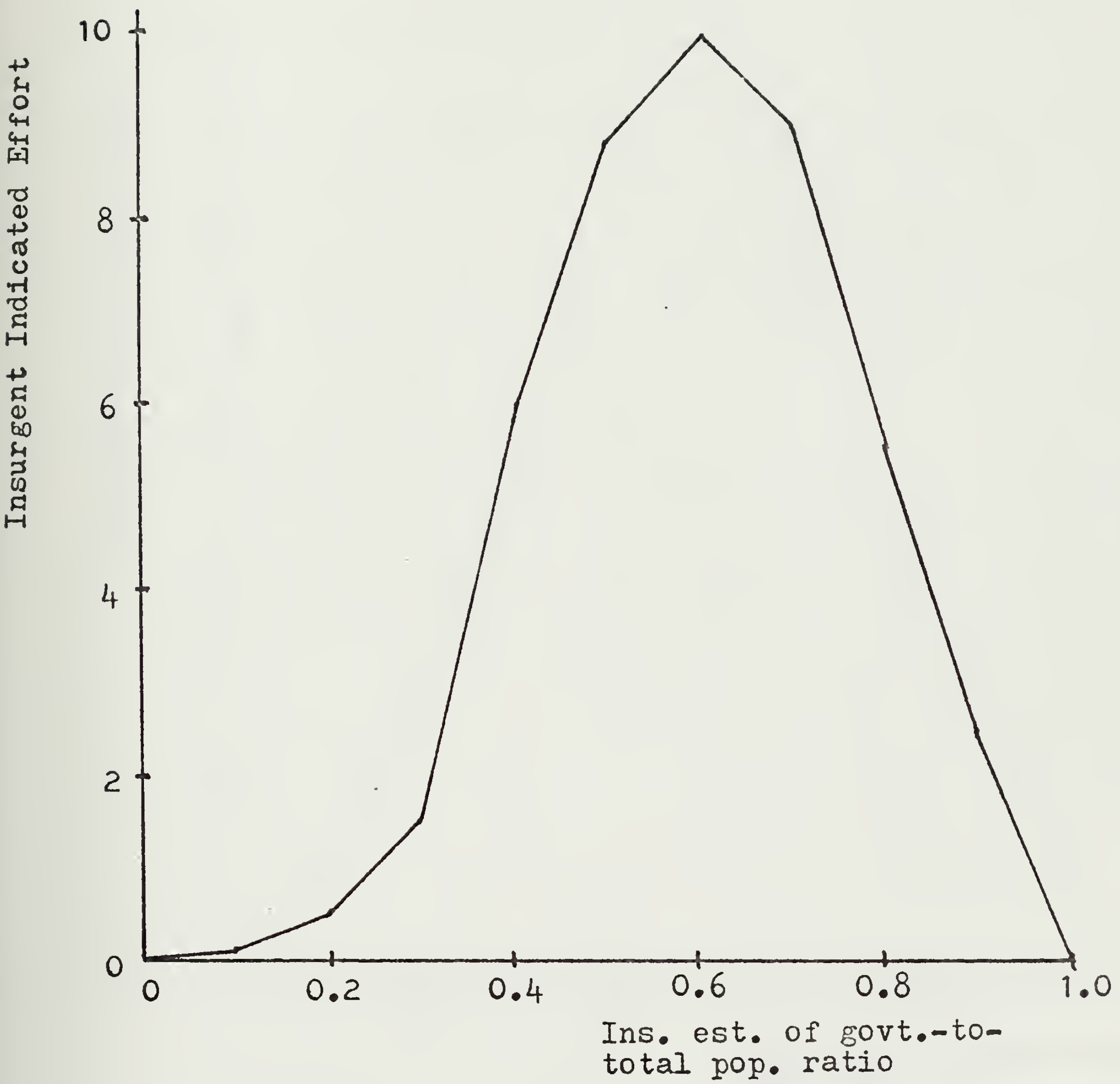


FIGURE 1

Indicated Insurgent Propaganda Effort

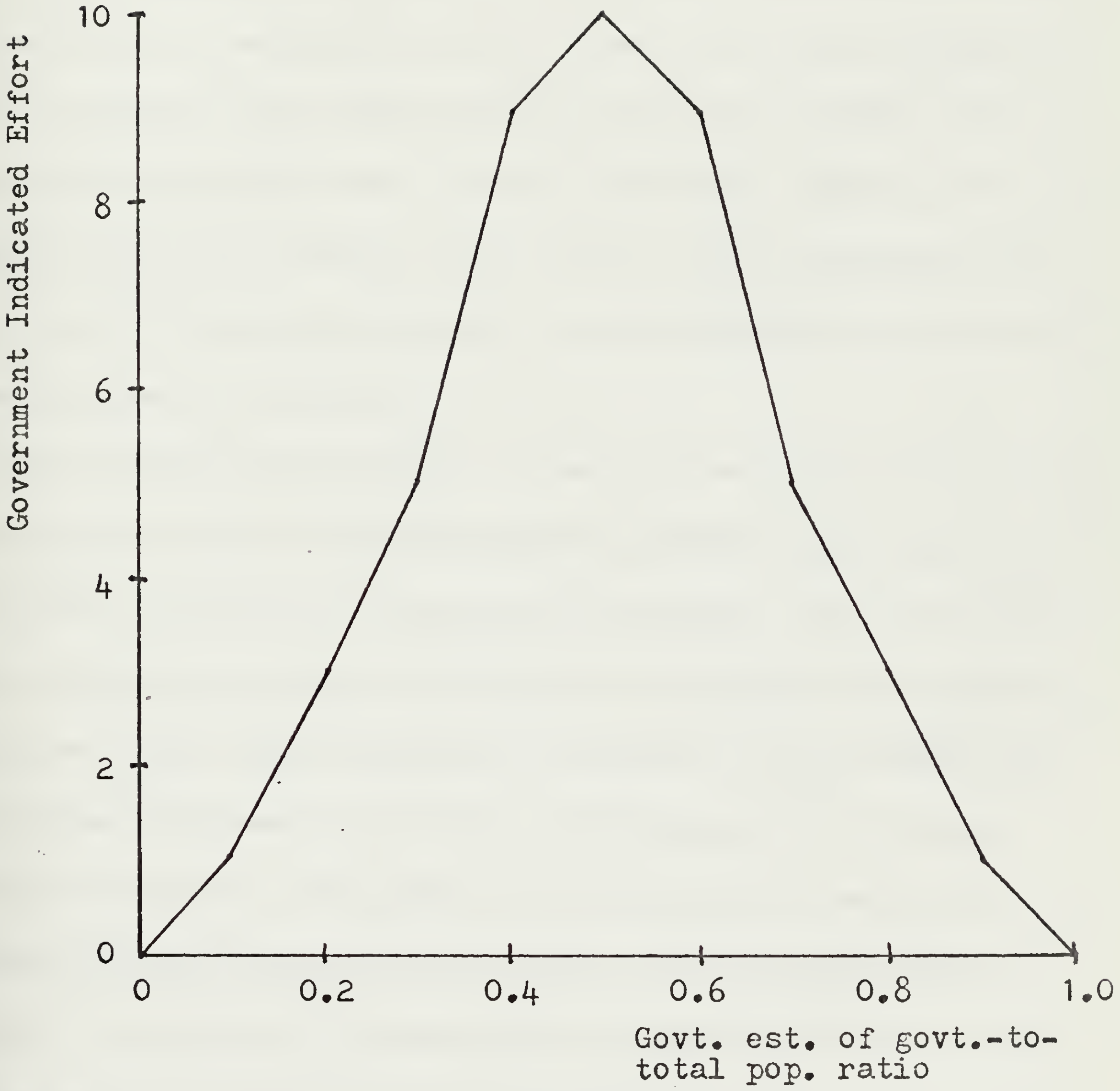


FIGURE 2

Indicated Government Propaganda Effort

be for each side based on the current government share of the population. When the government-oriented population is large relative to the total population, the insurgent population will be relatively small and concerned mainly with building popular support through propaganda. On the other hand, as the government's share of the population becomes small, the insurgent force will probably become more oriented toward pure military action, designed to drive the government completely from power. The government's propaganda effort is largely undisturbed, except at the extreme ends, by the character of the conflict. This is undoubtedly true because the government is more able to conduct operations simultaneously in both spheres of the conflict.

Once the decision-making process has produced values for the propaganda effort for both sides, the propaganda probability coefficients must be derived. In Chapter III, Description of the Model, it was shown that these coefficients represent the probabilities associated with six events, (1) neutral citizen changes allegiance to insurgents, (2) government citizen changes allegiance to insurgents, (3) government citizen changes allegiance to neutral, (4) insurgent changes allegiance to neutral, (5) insurgent changes allegiance to government, and (6) neutral changes allegiance to government. The probabilities associated with each of these six events are computed as follows

$$
\begin{aligned}
&P(\text{x changes to y this time period})\\
&\quad = P(\text{govt. or ins. propaganda reaches a citizen})\\
&\quad \cdot P(\text{the citizen is x})\\
&\quad \cdot P(\text{govt. or ins. propaganda changes x to y})
\end{aligned}
$$

The probability that a citizen is x (where x represents insurgent, government, or neutral) is simply the ratio of x citizens to the total population.

There are two functions (Figures 3 and 4) which relate propaganda effort to the probability of reaching a citizen, one for the government and one for the insurgents. The two curves in Figures 3 and 4 are similar: at low effort levels the probability of reaching a citizen is low, in certain ranges the incremental return for an increase in effort is large, and at higher effort levels, diminishing marginal returns are experienced. These ideas may be intuitively appealing since one would expect that at the lower levels of effort propaganda would either be highly specialized or spread very thinly over the entire population. Furthermore, one might expect that as the effort increases, more and more people are exposed to propaganda. Finally, the diminishing marginal returns experienced reflects a situation in which the main portion of the population becomes saturated with propaganda and the more elusive segments of the population remain to be reached (e.g., insurgents trying to reach middle-class citizens of large government controlled population centers).

The two curves for the probabilities of reaching citizens with propaganda differ in that insurgent propaganda is portrayed as being generally more effective in reaching the population. The insurgents have the advantages of being close to the people and of having only one area in which to concentrate their effort.

The functions representing the probabilities of propaganda causing citizens to shift from one faction of the population to another are found in

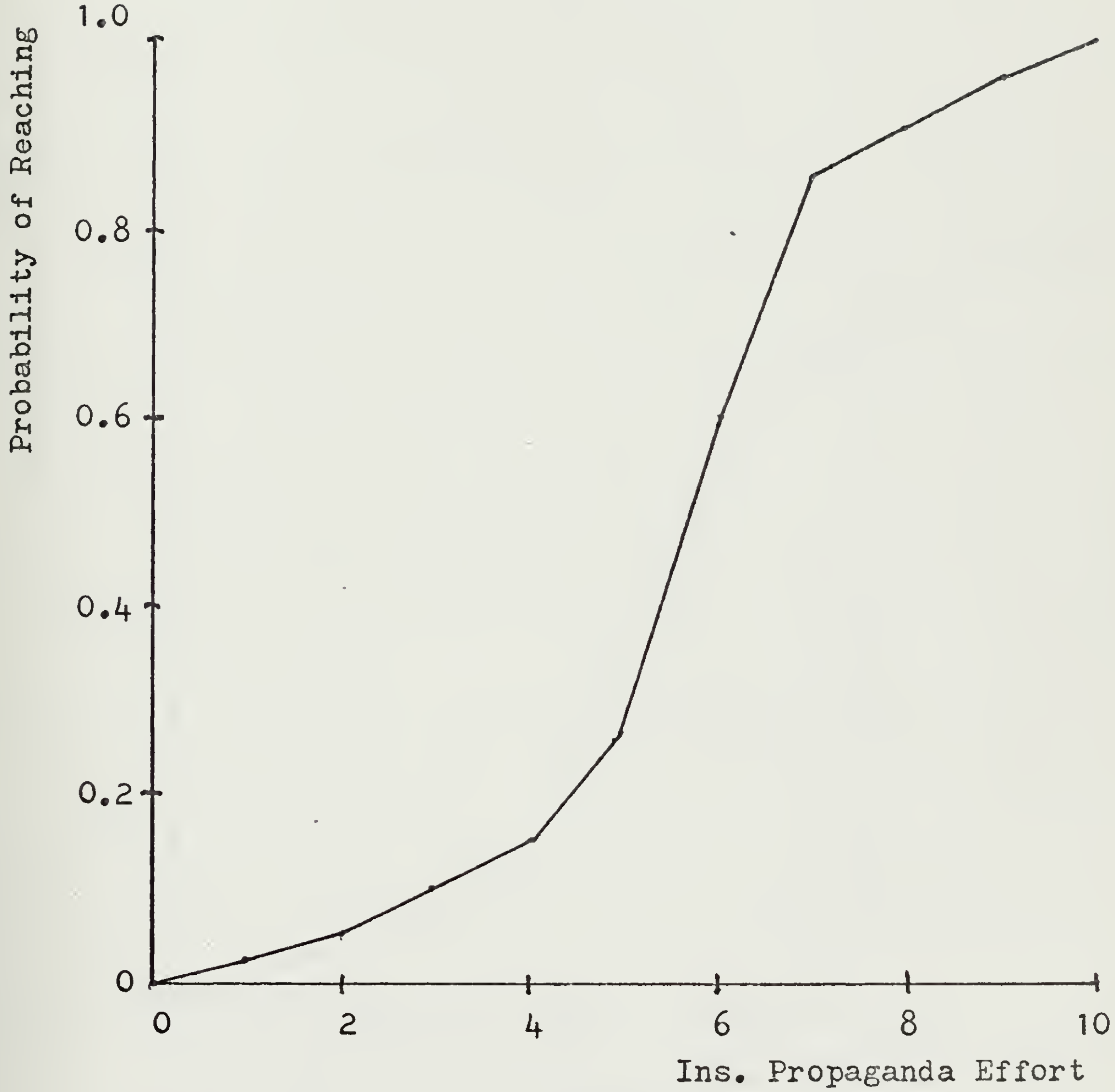


FIGURE 3

The Probability that Insurgent
Propaganda Reaches a Citizen

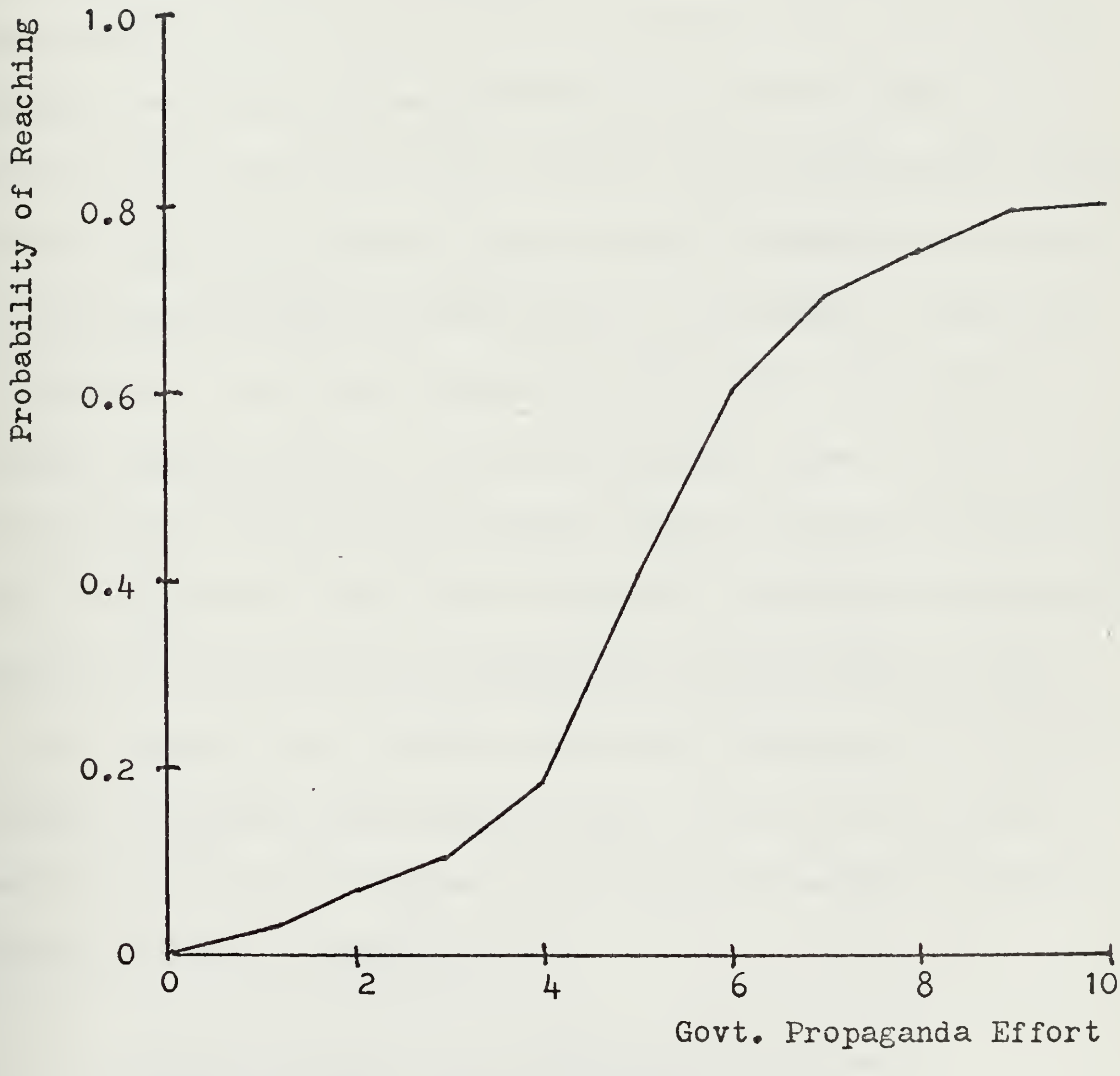


FIGURE 4

The Probability that Government
Propaganda Reaches a Citizen

Figures 5 through 10. These functions, reflecting the results of government and insurgent propaganda efforts, differ only in that the insurgents are represented as having the advantage of greater effectiveness in winning over the neutral population and that their own people are less prone to becoming neutrally oriented than are the government's. These two differences are not hard to believe when one considers, once again, that the insurgents are closer to the population and are, therefore, able to bring more pressure to bear on the neutral faction. Also, the government citizens probably would be more likely to become neutrally oriented than insurgents. One can reason that when a citizen becomes an insurgent, he makes more of a commitment, both physically and psychologically, than he does to the better established and more familiar government cause. Finally, that neither side has much success in directly converting citizens of the other side is not unrealistic since a shift of this type is probably psychologically difficult and may be fraught with danger for the person making the shift.

In the military sector, the tone of activity is determined by the number or troops the insurgent group has in the field. The size of the insurgent troop force is structured to depend on the size of the insurgent population relative to the total population, or,

$$\text{INSURGENT TROOPS} = (\text{percentage})\ (\text{no. of insurgents}),$$

where "percentage" is found by entering the function described in Figure 11 with the ratio of insurgents to the total population. A curve such as the one shown in Figure 11 is plausible for several reasons. First, when the

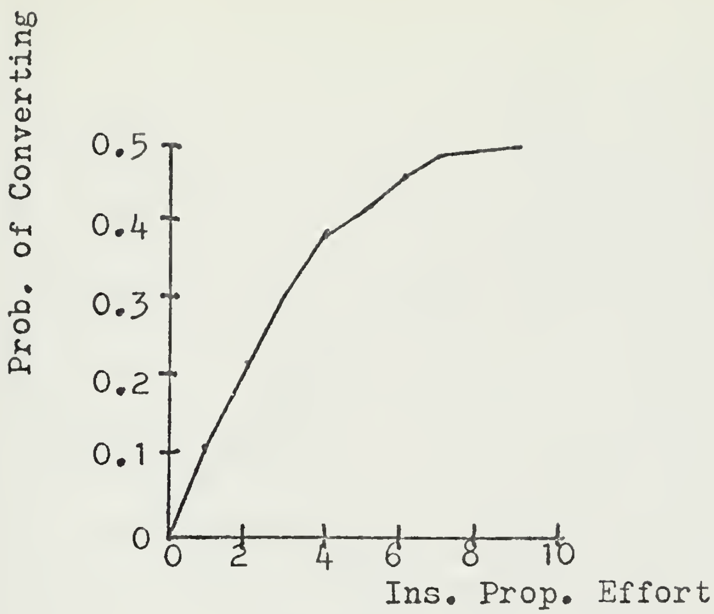


FIGURE 5

The Probability of Converting
Neutral to Insurgent

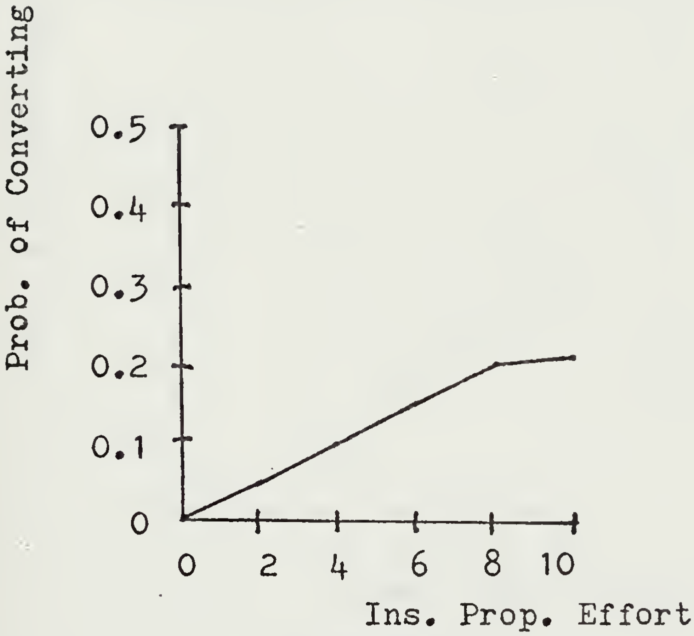


FIGURE 6

The Probability of Converting
Government Citizen to Insurgent

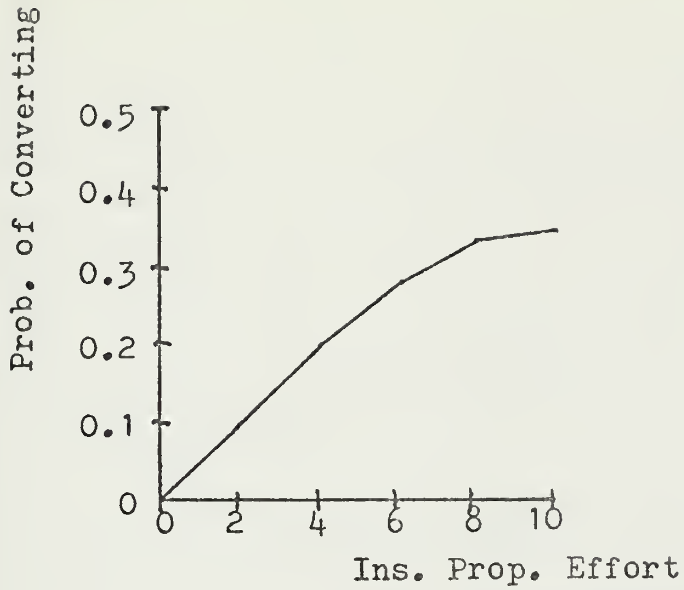


FIGURE 7

The Probability of Converting
Government Citizen to Neutral

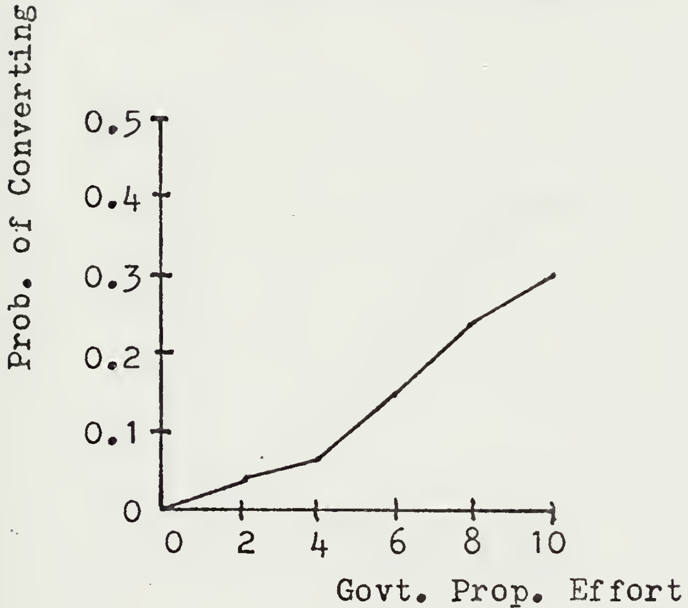


FIGURE 8

The Probability of Converting
Insurgent to Neutral

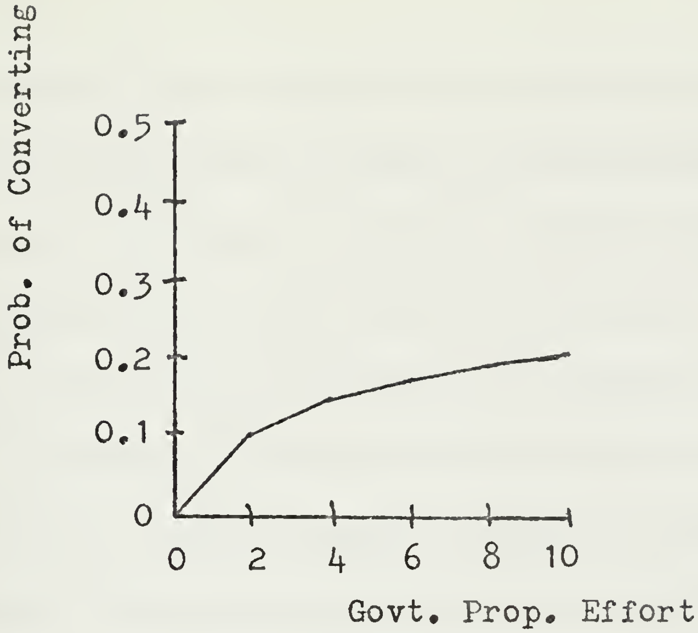


FIGURE 9

The Probability of Converting
Insurgent to Government

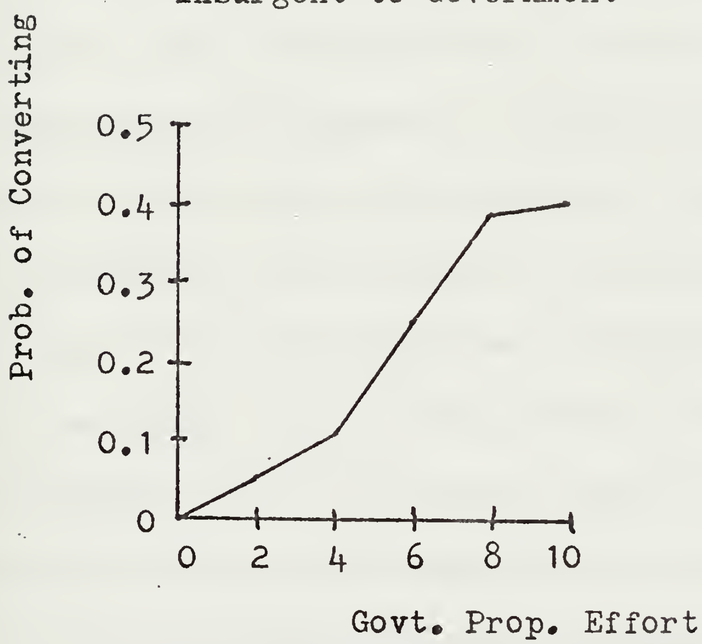


FIGURE 10

The Probability of Converting
Neutral to Government

insurgent share of the population is small the emphasis will not be on combat but on building popular support through propaganda. Therefore, only a small portion of the total force needs to be dedicated to military tasks. As the insurgent group grows, the emphasis begins to shift toward military action, and the fraction of the total force employed as troops increases. There is, however, a maximum value that this percentage can take on (in this case, 0.7). After this point, when the total force is large, increased logistic and administrative requirements will undoubtedly necessitate reduction of the portion of the force dedicated to combat duties.

The insurgent force is represented as having the capability to replace any troops lost through combat attrition in the time period following the loss. Government troop replacement is treated as being subject to slightly more complex decision rules, beginning with an "indicated" troop requirement. The indicated troop requirement for the government is established in any time period through the functional relationship shown in Figure 12. There are two salient features of the function for indicated government troop requirements. First, in the area of Figure 12 called guerrilla warfare, the government has constant indicated strength requirement of 1000 troops. Second, in the area of the figure labeled conventional warfare, the relationship between government troop strength and perceived insurgent troop strength is linearly increasing. The feature of the indicated government troop strength function concerning the change in the relationship between indicated government strength and perceived insurgent strength at a level of 1000 insurgent troops, recognizes the probable fact that as insurgent

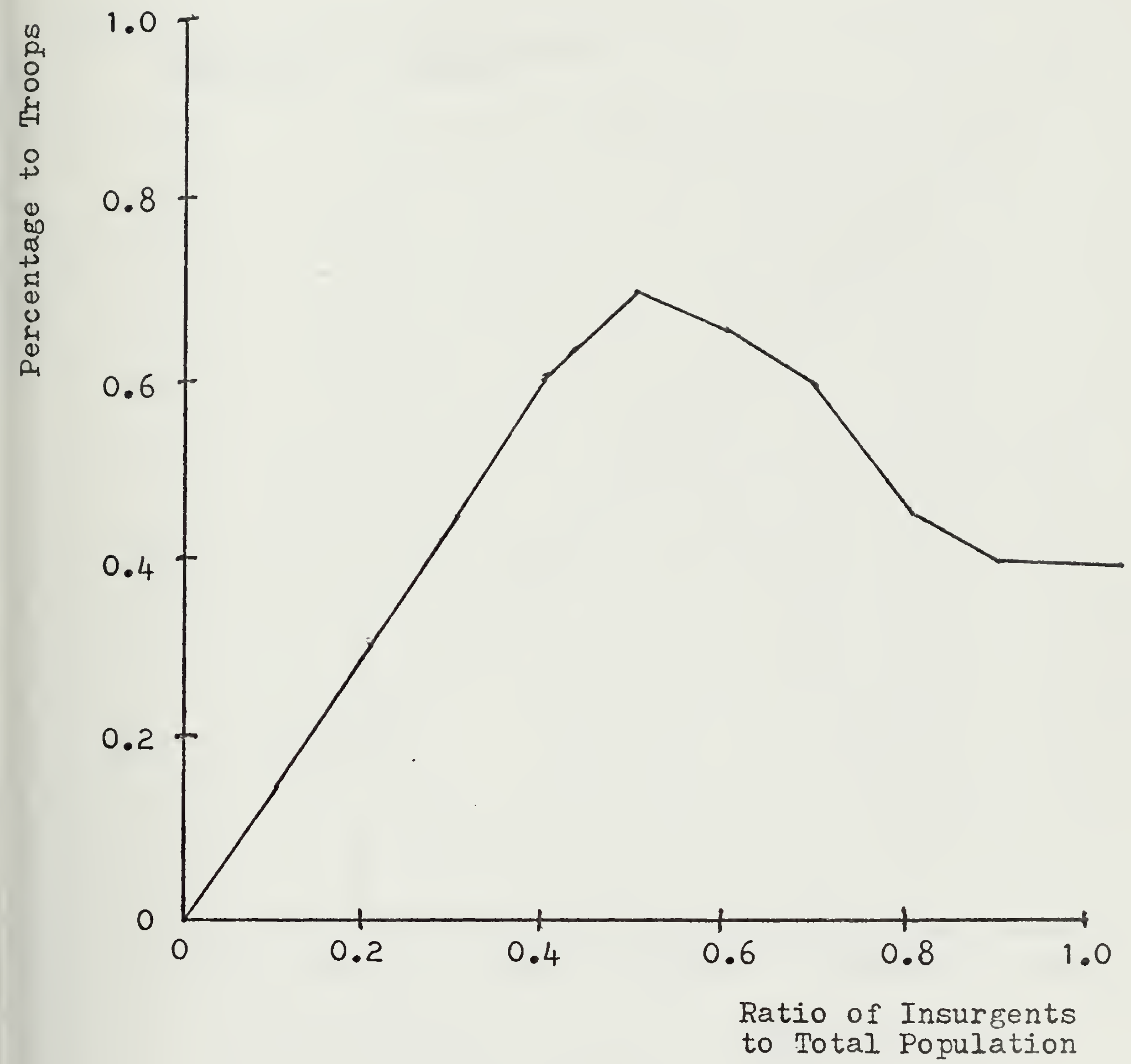


FIGURE 11

The Percentage of the Insurgent
Force to be Devoted to Troops

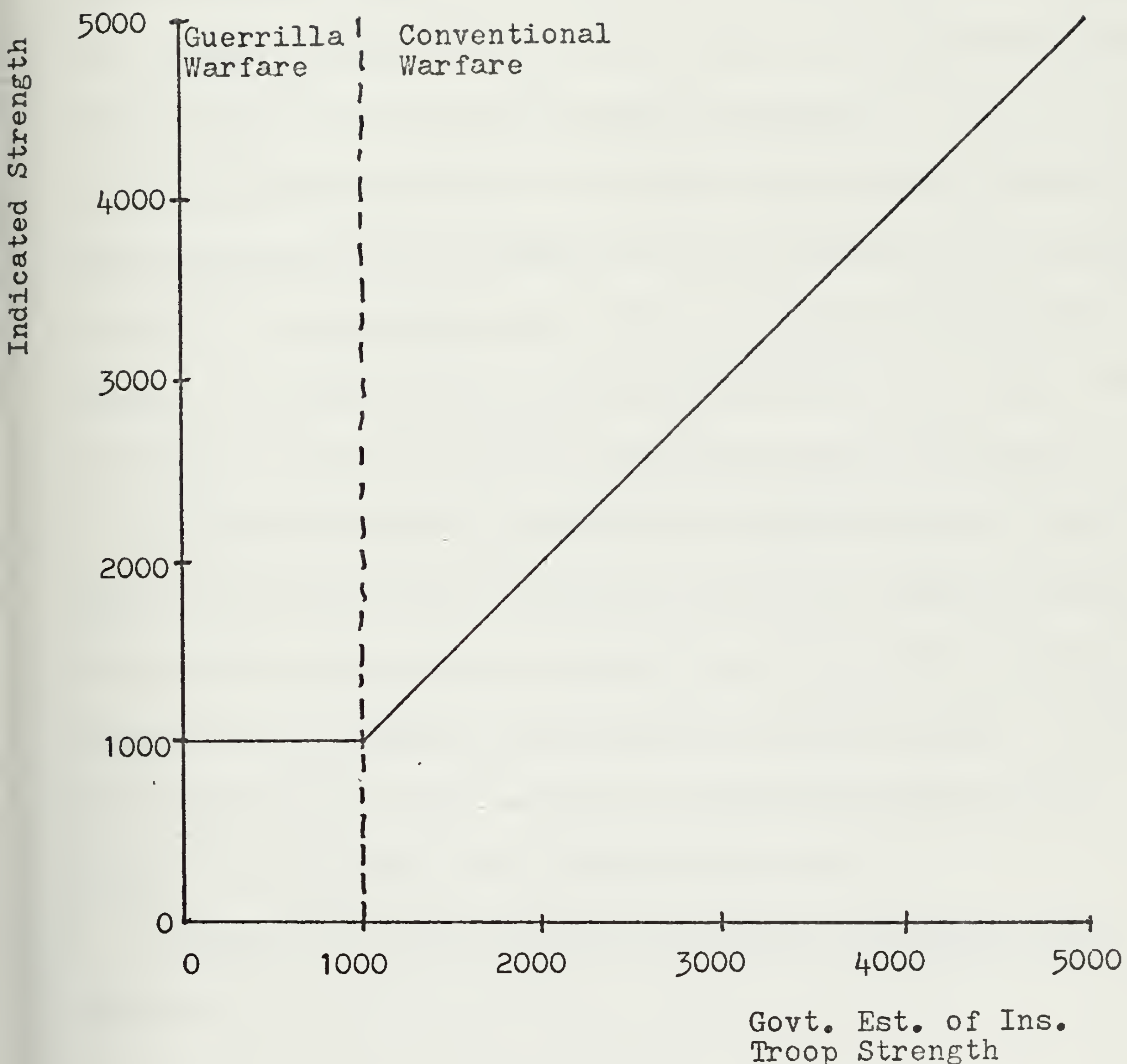


FIGURE 12

The Indicated Government Troop Strength

strength grows, battle will begin to take on more of the charactistics of conventional warfare. That is, when the insurgent military force is small a high ratio of government troops to insurgent troops is desirable for the government side. When the insurgent force becomes larger they will probably begin to engage more freely with the government forces in large unit operations, allowing the government force to use more sophisticated weapons, lessening the need for numerical superiority.

The government perception of insurgent troop strength is derived in the same manner as the government intelligence estimate of total insurgent strength in the propaganda sector. That is, the actual insurgent troop strength is modified by a government intelligence error coefficient. This coefficient provides for a uniformly distributed error of $\pm$ 20 percent.

The indicated government troop strength obtained from the function shown in Figure 12 is used in several decision rules which cumulatively determine the actual strength maintained in any time period. However, the initial value for government troop strength is taken as the first value of indicated strength. These decision rules will be discussed after an analysis of the attrition portion of the military sector.

Chapter III gave the equations for government and insurgent troop attrition as

$$\text{GOVT. ATTRITION} = \text{FCI} \cdot \text{TTI}$$

and $\text{INS. ATTRITION} = \text{FCG} \cdot \text{TTG} \cdot \text{IC}$,

where FCI and FCG are insurgent and government fighting constants which

take on values as shown in Figures 13 and 14. Chapter III described TTI and TTG as the total troops involved in combat for the insurgents and the government in any time period, and IC was shown to be a variable equal to 1000 if the insurgent troop strength is greater than 1000 and equal to TTI if insurgent troop strength is less than 1000. The total troops involved in combat for both sides is simply equal to the troop strength for each side if insurgent troop strength is below 1000. When insurgent troop strength becomes greater than 1000, TTI and TTG are equal and derived from the following relationship

$$\begin{aligned} TTI = TTG = &\ (\text{expected no. of engagements}) \\ &\cdot (\text{average force size}), \end{aligned}$$

where the expected number of engagements and average force size for both sides are obtained from the functional relationships in Figures 15 and 16, respectively.

The functions shown in Figures 13, 14, 15, and 16 undergo a fundamental change at the 1000-troop level for insurgents. The two functions for the fighting constants are fixed at 0.1 and 0.0001 for the insurgents and the government respectively until an insurgent troop level of 1000 is achieved. The functions for expected number of engagements and average force size are also constant up to the 1000 insurgent troop level. These changes reflect the movement away from guerrilla warfare toward more conventional warfare. The expected number of engagements increases from one per time period to a maximum of thirty per time period.

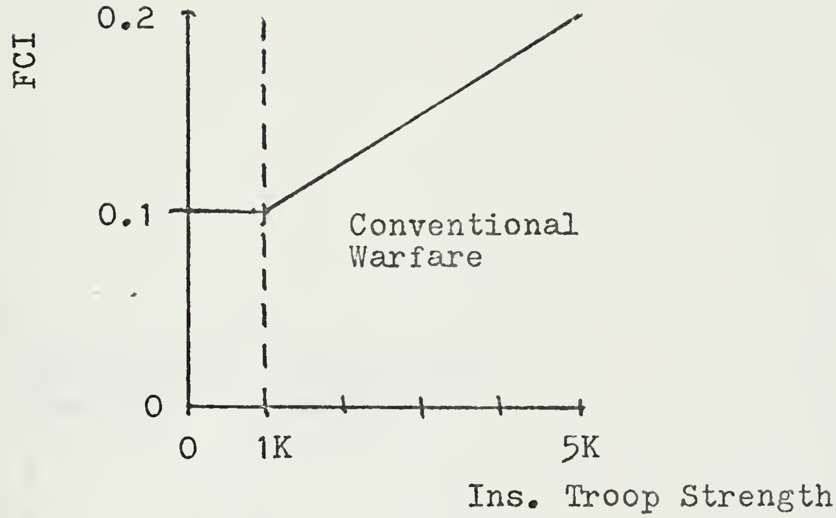


FIGURE 13

Insurgent Fighting Constant

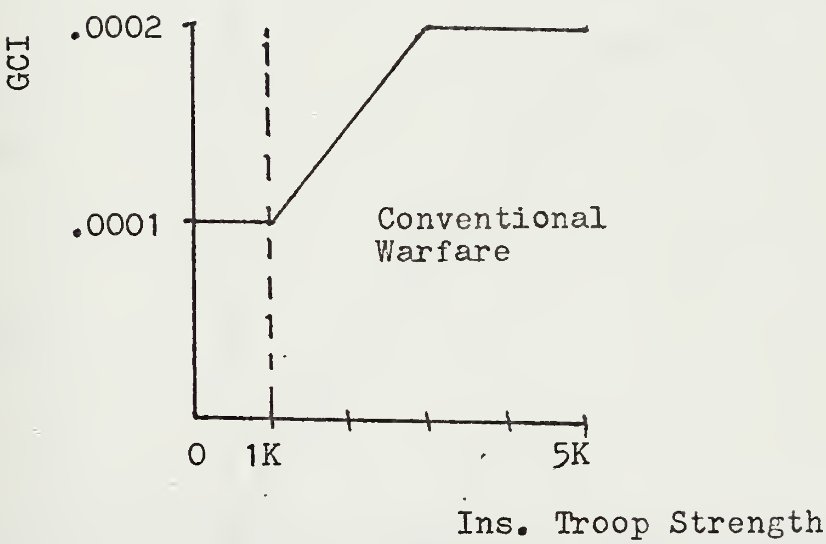


FIGURE 14

Government Fighting Constant

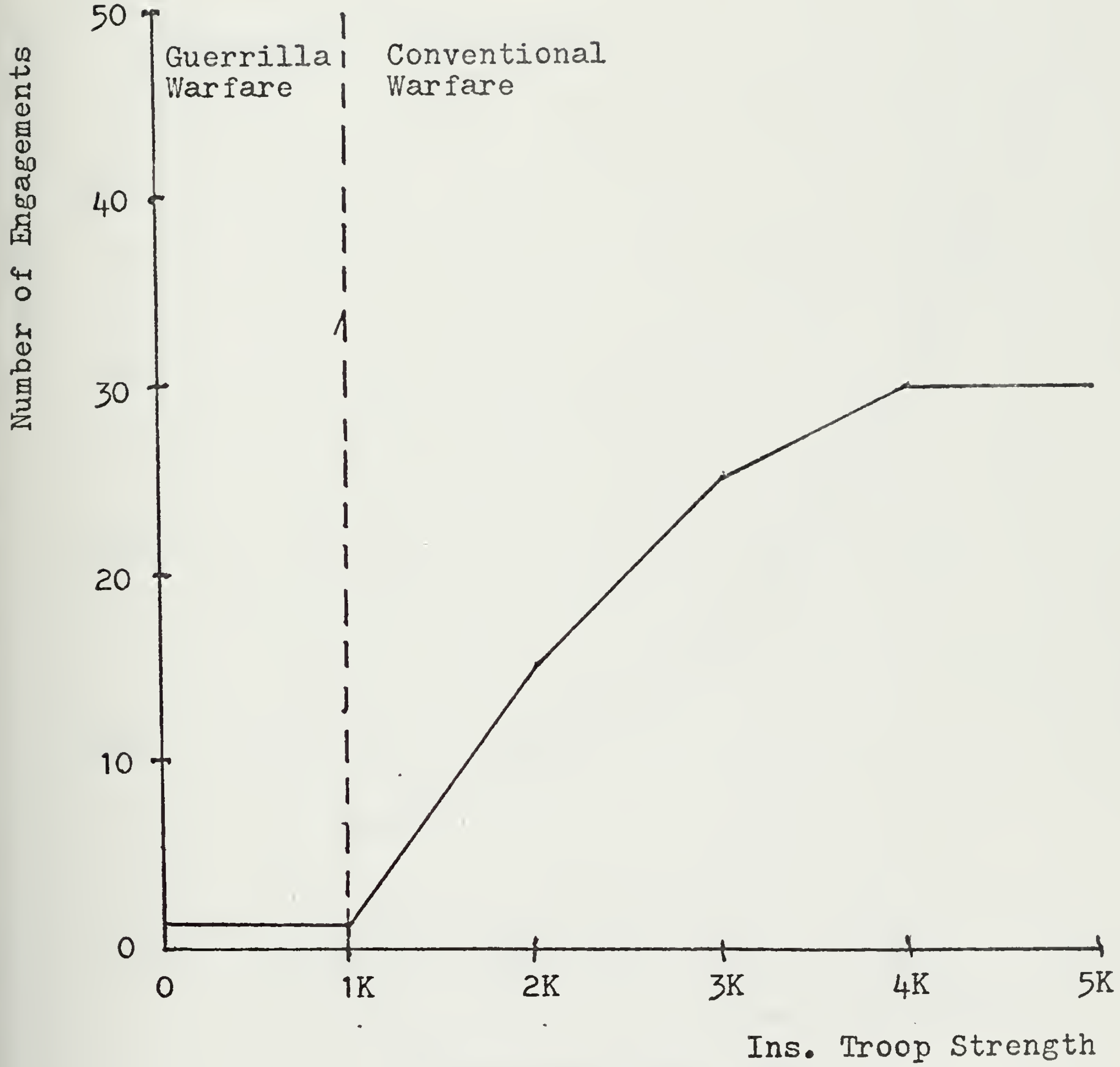
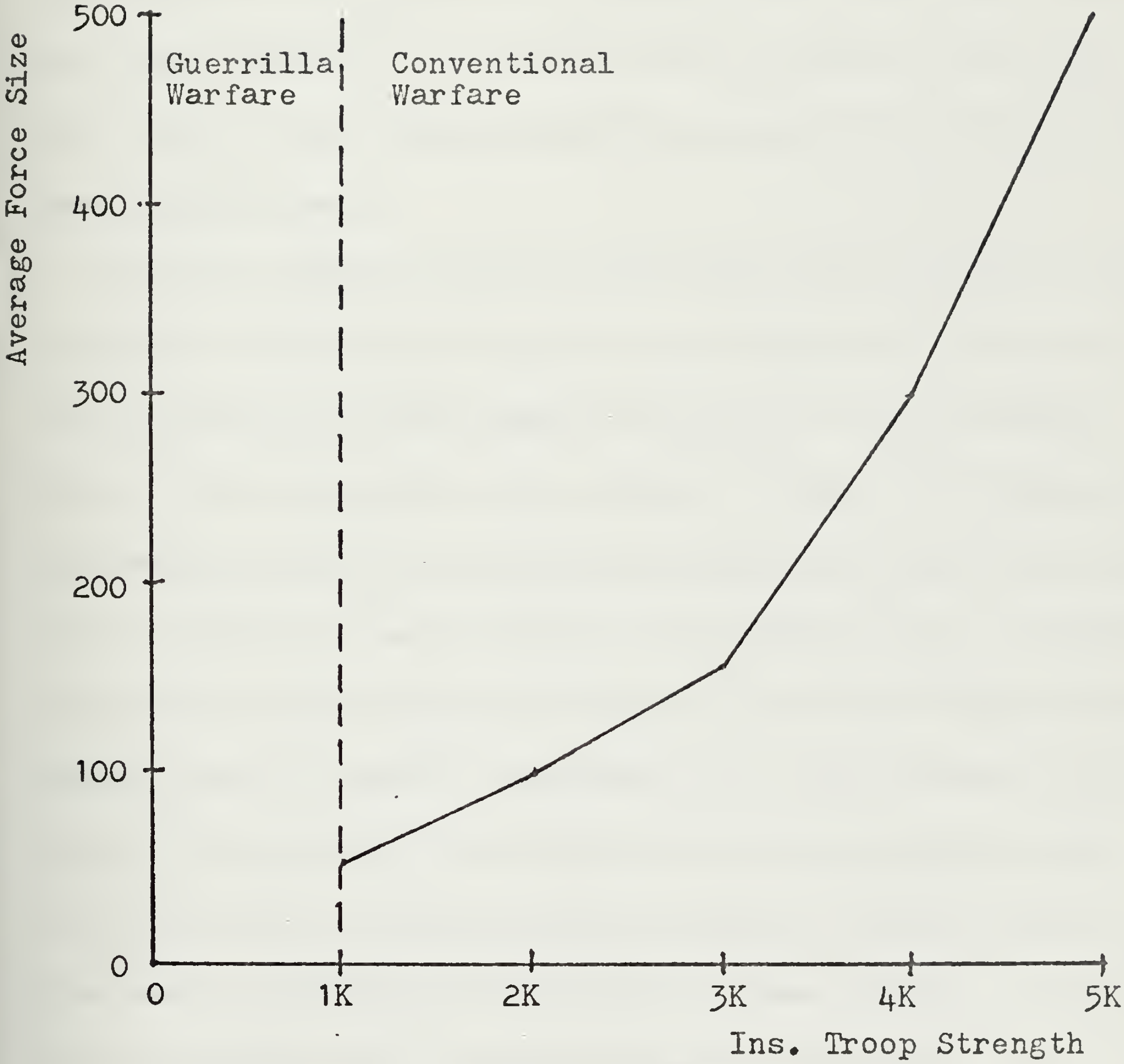


FIGURE 15

The Expected Number of Engagements



The Average Force Size

FIGURE 16

When less than 1000 insurgent troops are present, the force size for both sides is automatically set at their total troop strength. This procedure, coupled with the constant value of 1.0 for expected encounters, has the effect of entering the entire troop strength of each side into the attrition equations when the insurgent army strength is below 1000 troops. We shall see in Chapter VI, that this procedure is justified in view of the fairly realistic results obtained from the simulation in the area of guerrilla warfare attrition rates.

The fixed fighting constants for both sides during the guerrilla warfare phase imply that the state of warfare is somewhat static. Neither side is able to improve its position relative to the other in terms of weaponry because of the skirmish-like characteristics of battle in guerrilla warfare. Once warfare moves into the conventional stage, both sides improve their weapons efficiency linearly with time. The government force is allowed to do this more rapidly because it presumably has more resources available for this purpose. Moreover, the constant, IC, in the insurgent attrition equation remains fixed at 1000 after the shift to conventional warfare. This has the effect of maintaining the government's fighting constant on the same order of magnitude as the insurgent's. These changes accomplish the shift in Lanchester's equations discussed in Chapter III, from insurgents using aimed fire and government forces using area fire in the guerrilla warfare stage to aimed fire for both sides in the conventional warfare stage.

With comabt attrition occurring in every time period, troop replacement is naturally a subject of interest for both sides. Chapter III outlined the

decision rules for troop replacement. We will now examine the factors behind those decision rules.

Earlier in this chapter it was mentioned that the insurgent force is allowed to replace its losses, man for man, in the time period following the one in which they were incurred. This should be a reasonable procedure since the pool of men from which they draw replacements is present in the area in which they operate. Additionally, the "percentage rule", which each time period establishes the fraction of the total insurgent population to be devoted to troops, will never allow the insurgents to exceed their available manpower.

The government force, on the other hand, has some quite different troop replacement problems. First, the government military force is split between police and regular troops. The police must be recruited from the local population, and the regular troops are replaced from sources outside the system (that is, outside the contested area). Additionally, in the matter of maintaining a sufficient force in the system (area) under study, the government is of course concerned with making best use of its resources (troops). For this reason, then, the government must have decision rules not only for correcting troop shortages in the system but for removal of troops in excess of the number desired as well.

We previously discussed the procedure for computing indicated government troop strength through a functional relationship dependent on perceived insurgent troop strength. In the simulation, this value is compared with present total troop strength, police and regulars, to find shortages or

surpluses. The disparity for police forces is noted first. The number of police desired is determined by a fixed (user supplied) ratio of police to the population, 0.05 in this simulation. If a police shortage exists, the number required is added to the force after a recruiting and training delay of three months. Any police in excess of those required are removed only through combat attrition. Shortages in the number of regular troops are replaced after a delay of three time periods (months). The replacement troops begin arriving after three time periods, but the entire replacement requires several time periods for completion.

Removal of a surplus in the number of regular government troops is accomplished after a delay of the same magnitude and type as that for regular troop replacement. A rule reflecting the government's desire to take advantage of economy of scale is used in the decision-making process for troop withdrawal. The rule allows troop withdrawal in a time period only if the number of surplus troops exceeds 100 men.

In this chapter, we have discussed the assumptions which are input for the insurgency growth simulation. The next chapter will be devoted to a description of some of the results obtained from the computer simulation.

VI. SIMULATION RESULTS

In this chapter, we will investigate some of the results obtainable from the insurgency growth simulation. The hypothetical data used as input for the simulation runs to be discussed here are essentially the same as those discussed in the previous chapter. All the simulation runs were for 60 time periods, which corresponds to 5 years in the time context of the equations of the model. Simulation runs were conducted for a variety of initial population profiles, which ranged from 20 percent of the total population for the government and 1 to 5 percent for the insurgents. A short discussion of the format of the output from a DYNAMO program will preceed the discussion of the actual output of the simulation.

A. OUTPUT FROM THE DYNAMO COMPILER

The DYNAMO compiler provides for two forms of output: tabular and graphical. The tabular output allows the user to print any quantity desired. Time is automatically printed in the leftmost column. The user may specify the quantities to be printed in each of fourteen remaining columns. The variable name of the quantity to be tabulated is printed at the top of the page. The scale factors used are printed under each variable name. The DYNAMO compiler will provide automatic scaling if desired, or the user may specify the scaling of the quantities to be printed. All variables classified as levels or auxiliaries (intermediate results) correspond to the instant of time indicated in the row in which they appear. Rates, such as

population generation and attrition, on the other hand, correspond to the interval from the current time period to the next. In other words, the government troop attrition rate for time period i would actually correspond to the attrition rate over the interval (i, j).

The graphical form of output in DYNAMO provides a time-dependent plot of the simulation output quantities. Up to ten quantities may be specified for each plot. The user may plot all quantities on the same scale, specify different scales for the quantities, or let the DYNAMO complier choose the most convenient scales for the quantities to be plotted. In any case, the variable names appear to the right of the appropriate scales at the top of the graph. The plotting symbols for the variables are also indicated at the top of the graph.

B. VARIABLES AS INSURGENCY INDICATORS

There are several quantities which may be obtained as output from the simulation which will serve as useful indicators about the progress of the insurgency. The most obvious indicators are the population profiles at any time. The values for the insurgent, government, and neutral populations describe the state of the system in absolute terms. The ratios of insurgent, government, and neutral populations to the total population also yield this information in a more easily absorbed, relative form.

In the propaganda sector it is desirable to present the relative effectiveness of government and insurgent propaganda. Two expressions which yield a measure of relative propaganda effectiveness for a particular time period are the ratios of the number of citizens changing their allegiance due to

government propaganda to the government propaganda effort and the number of citizens changing their allegiance due to insurgent propaganda to the insurgent propaganda effort. The numerators of these expressions include all changes in allegiance in a time period. For example, included in changes of allegiance due to government propaganda are insurgent-to-neutral, insurgent-to-government, and neutral-to-government.

There are two types of useful indicators to be found in the military sector of the model. The first of these is a running total of the government and insurgent troops killed in combat. The second is the computation of an exchange ratio at the end of each time period as follows,

$$\text{Exchange Ratio} = \frac{\text{Govt. killed (i)}}{\text{Ins. killed (i)}} .$$

Two additional indicators which might be useful in describing the overall dynamics of the insurgency system at any time are variables which will yield the percentage change in the government and insurgent populations over each time period. These variables take the form,

$$\text{Govt. \% change (i, j)} = \frac{\text{Govt. pop. (j)} - \text{Govt. pop. (i)}}{\text{Govt. pop. (i)}}$$

and

$$\text{Ins. \% change (i, j)} = \frac{\text{Ins. pop. (j)} - \text{Ins. pop. (i)}}{\text{Ins. pop. (i)}} .$$

These variables are useful not only in a relative sense, that is, for a

direct comparison of government and insurgent rates of increase or decrease in population, but in an absolute sense for studying the behavior of the system. In other words, as the rates of increase or decrease for both sides become small, the insurgency system is clearly slowing down to a form of equilibrium.

The indicators just discussed along with the values of other variables will now be used to describe the output obtained from several simulation runs. Two forms of output will be employed. One will be essentially military, with exchange ratios, the running totals of troops killed, the troop levels for each time period, and variables describing the troop replacement process. The other form of output will involve population quantities and ratios as well as the propaganda effectiveness indicators.

The most interesting output is that for which the initial population profile is heavily neutral. Specifically, the results selected for study in detail are from the simulation run with an initial neutral population of 79 percent (7900), an insurgent population of 1 percent (100), and a government population of 20 percent (2000). This particular simulation run was selected because it gives the best description of the entire spectrum of system activity. That is, as shown in Figure 17 both the insurgent and government populations begin small and grow relatively slowly up to the 20th time period. Until time period 29, the troop levels, Figure 18, are also small, allowing the observation of government and insurgent propaganda effects, as well as the guerrilla warfare phase, in the combat sector. After time period 29, troop levels increase, and at time 35 the insurgents have a

combat force in excess of 1000 troops. This allows the observation of the next phase of combat, conventional warfare, as well as the troop replacement procedures of the government side.

The results for the other initial population profiles (i.e. 30% - 60% government and 5% insurgent) are similar to those of the run which is being examined, in that the growth patterns are essentially the same for the populations and troops. Also, the approximate ratio of insurgent population to government population after 60 time periods is .70, for all initial population profiles. The important difference in the output between the 1% - 20% - 79% insurgent-government-neutral population profile and all other beginning profiles is the rate of population growth and the consequent rate of combat forces growth. With the larger initial allocations for government and insurgent populations we see an immediate rapid growth in the insurgent population and a rapid initial decrease in the government population. The principal cause for this anomaly is that the functional relationship for the insurgent propaganda effort depends on the ratio of government population to the total population (Figure 1). When this ratio is large initially, a high initial insurgent propaganda effort is dictated. This results in large initial gains for the insurgents.

The graphical output for the 1% - 20% - 79% initial population profile can be seen in Figures 17 and 18, and the tabled output is contained in Tables II through V. The growth in both populations in an absolute sense appears to be rather small until time 19. This is somewhat misleading since, as seen in Table III, the growth rates for the government and insurgent

populations per time period are 2% to 5% and 2% to 3%, respectively. However, since the populations are still small until time 19, the troop levels are low, as are the insurgent and government death rates. Obviously, troop replacement poses no problem for the government force during this interval.

At time 19 both the government and insurgent populations begin to grow rapidly. This just marks the beginning of rapidly increasing propaganda effort on both sides at about the time the government attains a 30 percent share of the total population (Figures 1 and 2 of Chapter IV). The insurgent troop force also begins to grow rather rapidly after time 19, but combat does not become a major consideration until about time 35.

At time 35, the insurgent combat force exceeds 1000 men for the first time. This marks the shift toward more conventional warfare. There are several characteristics of the output worthy of note after time 35. First, the rates of change become severely dampened by combat, during this phase of more conventional warfare. The government and insurgent population ratios are high at time 35 and, as a consequence, the propaganda effort on both sides is high. However, increased combat deaths on both sides produce net decreases in both populations.

In Table IV, it can be seen that the exchange ratio, or the ratio of government dead to insurgent dead, is almost constant at 2 for each time period up to time 34. At time 35, this exchange ratio begins to decrease. The decrease in the exchange ratio is explained by the increased ability of the government force to use superior weapons, as the character of the

conflict becomes more conventional. The changeover to conventional warfare can be noted in the rapid linear increase of the government fighting constant at the 1000-insurgent troop level in Figure 6, Chapter IV.

After the insurgent troop strength reaches 1000 men, according to Figure 5 in Chapter IV, the indicated government troop strength will match, on a one-for-one basis, the government intelligence estimate of the number of insurgent troops. From Tables IV and V, it is apparent that the indicated troop strength and the actual total government troop strength never match the actual insurgent troop strength. There are two reasons for this discrepancy. The first reason is that indicated government troop strength is based on an intelligence estimate of the actual insurgent troop strength. The error in this estimate is uniformly distributed between -20 percent and +20 percent. The discrepancies found in Figure 18 between indicated government troop strength and actual insurgent troop strength are found to be within these parameters.

The second reason for these discrepancies is attributable to delays in government troop replacement for both regulars and police as well as delays in excess troop withdrawal in the case of regulars. These delays cause the total actual troop strength to consistently lag indicated troop strength. The delays for regular troops and police replacement and the delay for regular troop withdrawal are cascaded. That is, a demand is made in time period i, and, after i + delay time periods, the demand begins to be satisfied. It is completely satisfied incrementally in each of several time periods thereafter. This is not readily apparent from looking at the output

data in Table V. However, one can see by comparing regulars desired with regulars added, regulars in excess of demand with regulars removed, and police desired with police added that there is clearly a lag in system response to demands placed upon it.

Finally, something should be said about the behavior of the system in the latter part of a simulation run. Between time periods 36 and 39, in the simulation run under consideration, the rates of change of the insurgent and government populations for each time period describe a transition to a period of relatively little net activity in the system. While the troop levels are still relatively high and propaganda effort is still being expended, the system has apparently settled down to a situation in which neither side makes appreciable gains or suffers appreciable losses in significant lengths of time. This pheonomenon is reflected in the ratios of government citizens to insurgents, insurgents to total population, and government citizens to total population as well as the rates of population change for each time period.

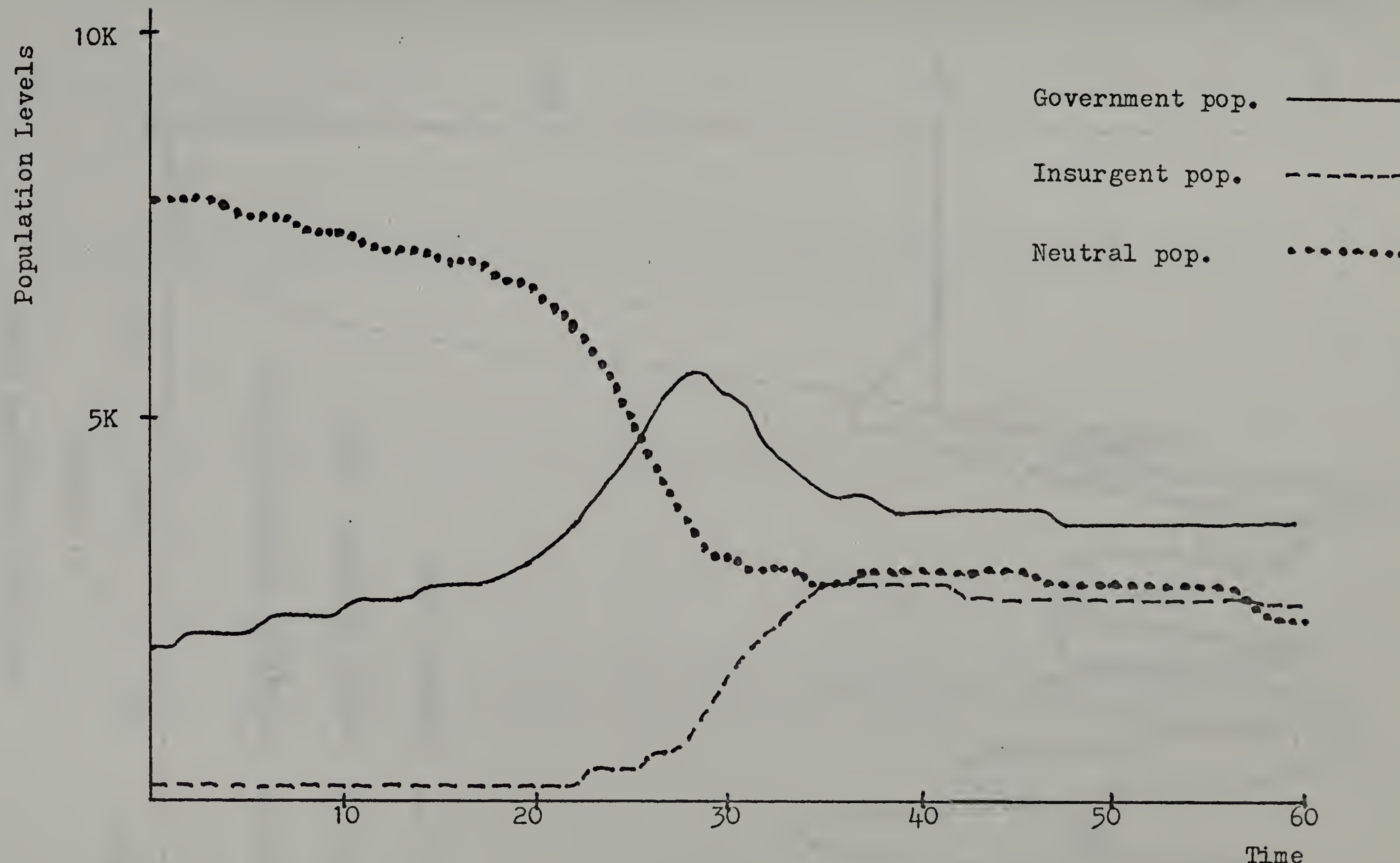


FIGURE 17

Population Variation with Time

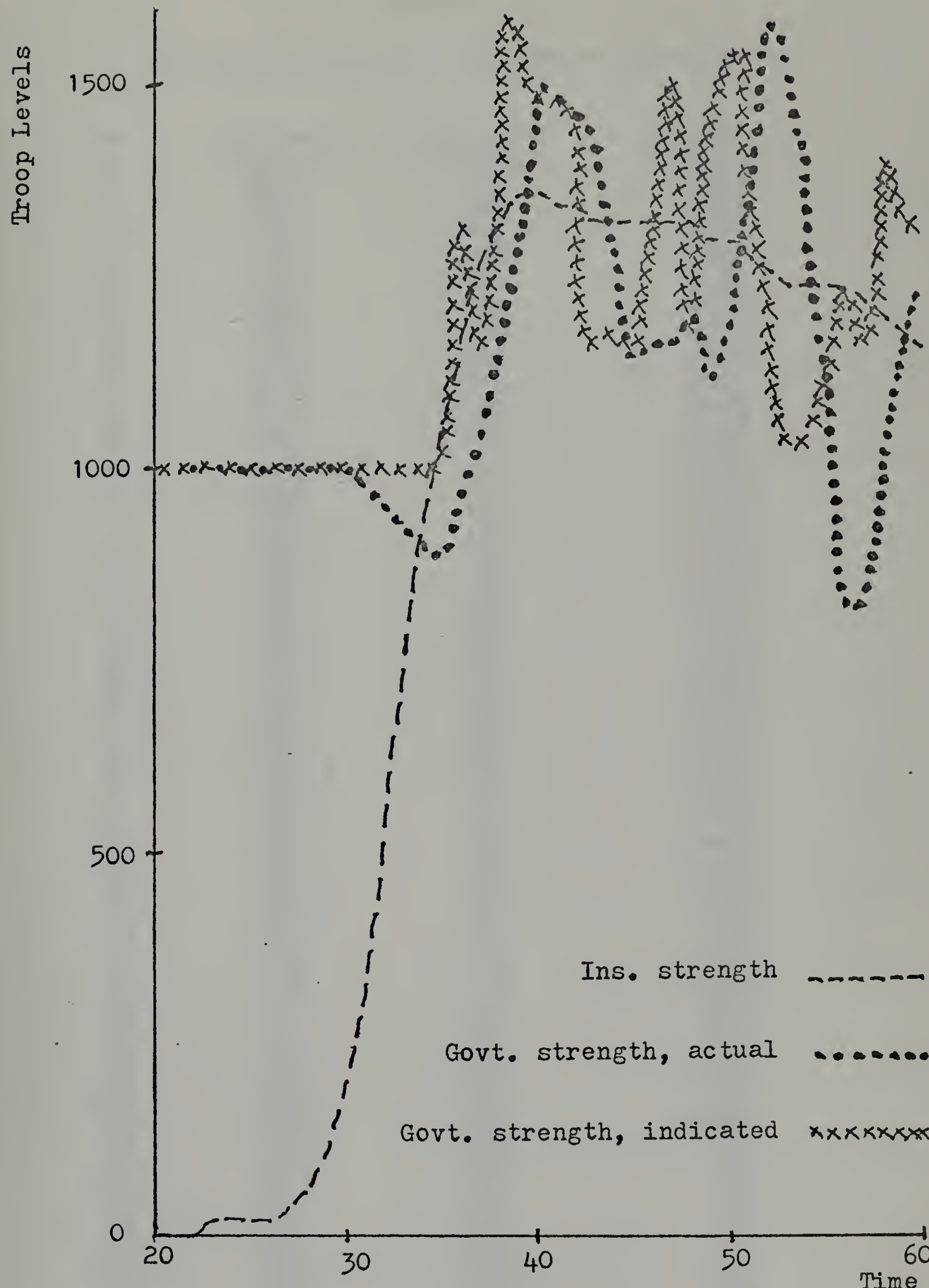


FIGURE 18

Troop Variation with Time

TABLE II

Simulation Results: Population Profiles

Time	Government Population	Insurgent Population	Neutral Population
0	2000	100	7900
1	2049	103	7848
2	2100	105	7794
3	2152	109	7739
4	2201	112	7687
5	2252	115	7632
6	2304	118	7577
7	2358	121	7520
8	2410	126	7463
9	2465	130	7403
10	2521	135	7342
11	2575	141	7282
12	2628	147	7223
13	2682	154	7162
14	2736	161	7101
15	2789	168	7039
16	2842	177	6978
17	2899	186	6911
18	2965	195	6835
19	3055	206	6734
20	3181	219	6594
21	3355	238	6401
22	3581	265	6147
23	3810	301	5881
24	4160	355	5476
25	4596	423	4972
26	5022	522	4444
27	5359	666	3961
28	5527	900	3554
29	5473	1208	3294
30	5266	1557	3140
31	4995	1906	3040
32	4692	2238	2974
33	4459	2480	2907
34	4258	2654	2860
35	4082	2776	2824
36	4007	2880	2783
37	3935	2944	2764
38	3869	2985	2751
39	3832	2990	2737
40	3821	2969	2720
41	3814	2942	2704
42	3801	2923	2690
43	3787	2907	2676
44	3760	2903	2664
45	3726	2905	2653
46	3709	2894	2637
47	3692	2879	2623

Time	Government Population	Insurgent Population	Neutral Population
48	3691	2851	2607
49	3674	2837	2594
50	3669	2816	2580
51	3663	2795	2568
52	3671	2765	2555
53	3673	2743	2543
54	3650	2744	2536
55	3644	2735	2523
56	3638	2722	2510
57	3651	2690	2496
58	3675	2649	2480
59	3698	2612	2467
60	3707	2591	2458

TABLE III

Simulation Results: Population Ratios and Growth Rates

Time	Ratio Ins. to Total Pop.	Ratio Govt. to Total Pop.	Govt. Growth Rate	Ins. Growth Rate
0	.01	.20	.000	.000
1	.01	.21	.024	.027
2	.01	.21	.024	.026
3	.01	.22	.024	.029
4	.01	.22	.022	.028
5	.01	.23	.023	.028
6	.01	.23	.022	.028
7	.01	.24	.023	.028
8	.01	.24	.022	.033
9	.01	.25	.022	.035
10	.01	.25	.022	.041
11	.01	.26	.021	.040
12	.01	.26	.020	.042
13	.02	.27	.020	.045
14	.02	.27	.020	.045
15	.02	.28	.019	.048
16	.02	.28	.018	.049
17	.02	.29	.020	.049
18	.02	.30	.022	.053
19	.02	.31	.030	.053
20	.02	.32	.041	.065
21	.02	.34	.054	.082
22	.03	.36	.067	.116
23	.03	.38	.063	.135
24	.04	.42	.091	.179
25	.04	.46	.104	.191
26	.05	.50	.092	.235
27	.07	.54	.067	.274
28	.09	.55	.031	.352
29	.12	.55	-.009	.341
30	.16	.53	-.037	.289
31	.19	.50	-.051	.223
32	.23	.47	-.060	.174
33	.25	.45	-.049	.108
34	.27	.44	-.045	.070
35	.29	.42	-.041	.045
36	.30	.41	-.018	.037
37	.31	.41	-.017	.022
38	.31	.41	-.016	.013
39	.31	.40	-.009	.001
40	.31	.40	-.003	-.007
41	.31	.40	-.001	-.008
42	.31	.40	-.003	-.006
43	.31	.40	-.003	-.005
44	.31	.40	-.006	-.001
45	.31	.40	-.009	.000

46	.31	.40	-.004	-.003
47	.31	.40	-.004	-.005
48	.31	.40	-.000	-.009
49	.31	.40	-.004	-.004
50	.31	.40	-.001	-.007
51	.31	.41	-.001	-.007
52	.31	.41	.002	-.010
53	.31	.41	.000	-.008
54	.31	.41	-.006	.000
55	.31	.41	-.001	-.003
56	.31	.41	-.001	-.004
57	.30	.41	.003	-.011
58	.30	.42	.006	-.015
59	.30	.42	.006	-.010
60	.30	.42	.002	-.008

TABLE IV

Simulation Results: Troop Profiles

Time	Insurgent Troops	Government Troops	Exchange Ratio
0	2	1000	2.00
1	1	1000	2.00
2	2	1000	2.00
3	2	1000	2.00
4	2	1000	2.00
5	2	1000	2.00
6	2	1000	2.00
7	2	1000	2.00
8	2	1000	2.00
9	2	1000	2.00
10	2	1000	2.00
11	3	1000	2.00
12	3	1000	2.00
13	3	1000	2.00
14	3	1000	2.00
15	4	1000	2.00
16	4	1000	2.00
17	5	1000	2.00
18	5	1000	2.00
19	6	1000	2.00
20	6	1000	2.00
21	7	1000	2.00
22	8	1000	2.00
23	10	999	2.00
24	13	999	2.00
25	18	999	2.00
26	26	998	2.00
27	39	997	2.00
28	65	995	2.00
29	119	991	2.01
30	221	986	2.02
31	381	974	2.04
32	582	949	2.07
33	780	918	2.12
34	937	896	2.16
35	1061	889	1.81
36	1200	973	1.50
37	1273	1047	1.38
38	1322	1189	1.31
39	1355	1305	1.27
40	1361	1501	1.26
41	1348	1479	1.28
42	1333	1452	1.30
43	1324	1419	1.31
44	1317	1309	1.32
45	1319	1142	1.31
46	1327	1152	1.30
47	1321	1157	1.31
48	1315	1194	1.32

Time	Insurgent Troops	Government Troops	Exchange Ratio
49	1298	1120	1.34
50	1293	1201	1.35
51	1280	1369	1.37
52	1268	1581	1.38
53	1248	1546	1.41
54	1236	1399	1.43
55	1242	1124	1.43
56	1236	816	1.43
57	1230	839	1.44
58	1207	989	1.48
59	1179	1196	1.53
60	1154	1482	1.58

TABLE V

Simulation Results: Troop Replacement Figures

Time	Regulars Desired	Regulars Added	Regulars in Excess	Regulars Removed	Police Desired	Police Added
0	0	0	0	0	0	0
1	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	0	0	0	0	0	0
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	1	0	0	0	1	0
26	1	0	0	0	0	0
27	1	0	0	0	0	0
28	2	1	0	0	2	0
29	5	1	0	0	6	1
30	8	2	0	0	5	3
31	13	4	0	0	5	4
32	26	7	0	0	21	5
33	51	13	0	0	47	13
34	82	26	0	0	51	30
35	103	45	0	0	18	41
36	111	64	0	0	4	29
37	337	80	0	0	0	17
38	120	165	0	0	0	8
39	387	150	0	0	16	4
40	267	229	0	0	35	10
41	0	0	30	0	9	22
42	0	0	6	0	0	16
43	0	0	225	0	0	8
44	0	0	255	75	11	4
45	0	0	129	135	26	7
46	24	31	0	0	14	16
47	143	29	0	0	0	15

Time	Regulars Desired	Regulars Added	Regulars in Excess	Regulars Removed	Police Desired	Police Added
48	340	67	0	0	0	7
49	0	0	15	39	20	3
50	332	105	0	0	32	11
51	340	181	0	0	0	21
52	164	234	0	0	0	10
53	0	0	346	7	0	5
54	0	0	514	120	7	2
55	0	0	365	251	16	4
56	0	0	25	289	9	10
57	434	41	0	0	0	9
58	325	172	0	0	12	4
59	420	223	0	0	28	8
60	145	288	0	0	1	18

VII. CONCLUSIONS AND SUGGESTED TOPICS FOR FURTHER RESEARCH

The foregoing development of an insurgency growth model using the systems approach has demonstrated that it is possible to model a system such as an insurgency in the whole. That is, it is possible to construct a model which not only includes the essential variables of an insurgency situation but their interactions as well. The remainder of this chapter will be devoted to recommendations for the expansion and refinement of the insurgency growth model.

Now that the basic framework has been constructed for the systems modeling of insurgency, it is apparent that the majority of the work necessary to produce a practicable insurgency model lies ahead. Within the structure of this beginning model, there are several refinements which could be made in both the propaganda and the military sectors. Refinements could be approached in either of two ways. First, one could select an existing or past insurgency and attempt to shape the model and its revisions to fit that insurgency, specifically. The second course would be to keep the model general by concentrating on attributes which insurgencies have historically held in common and by attempting to discern universal characteristics or trends in the behavior of those attributes and their relationship to each other. This second course has the advantage of usefulness in application to hypothetical or incipient insurgencies.

The variable called propaganda effort in this model is an aggregation of all the actions of a psychological nature the government or insurgent

sides could take. Propaganda, in this model, might also be defined as those actions by either side which are not purely military. Included in this variable are programs such as propaganda itself, education, control of the legal system, and civic action. One expansion of the basic insurgency model would be to build submodels for each of these, and perhaps other, programs. The main inputs for submodels such as propaganda, education and civic action would be variables such as money and manpower. The group undertaking the program (the government and the insurgents) would have to be implicitly scored on efficiency and the output could be a probability statement about the effectiveness of the program in persuading citizens to change their allegiance. Attributes such as the one for control of the legal system might be expressed as an absolute advantage in terms of contribution to the overall psychological effort of either side. That is, control of the legal system could be expressed as a percentage for both sides which might be dependent on some other variable such as physical control of territory. This percentage variable could then be used as a coefficient for the other psychological programs of both sides, yielding a net advantage in these programs to the side with majority control. Each of the major programs should also be weighted proportionally according to their contribution to the total psychological effort.

In the military sector of the model, the principal efforts should be aimed at more research. For example, it is clear that the government side in an insurgency situation will tailor the size of its combat force in a contested area according to its perception of the size of the insurgent combat force.

The subject for research would be to discover what general trends (if any) for government troop allocation are to be found in historical data and to apply those trends in the insurgency model. The same could be done for variables such as the expected total troops involved in combat in any given time period for various force levels on each side and the relationship between the insurgent share of the total population and the size of its combat force. Further, it is apparent that any system such as one for combat troop replacement and reenforcement has inherent delays attributable to such causes as recruitment, decision-making, training, and transportation. The topic for study in this area would be to first find the conditions which contribute to these delays and second to find the behavior of the delays under varying conditions. For example, as an insurgency becomes drawn out the delay due to decision-making is likely to shorten, while that portion of the total delay attributable to recruitment will likely become longer.

Two other areas for expansion in the insurgency model bridge the military and psychological sectors. These are the areas of taxation and troop recruitment. Generally speaking, it is unlikely that the insurgent force will recruit its combat troops directly from the population. Rather, the insurgents will, in all likelihood, form their combat force from the hard-core of its existing complement. On the other hand, the full-time insurgent group depends almost entirely on the local population for its livelihood. As the group becomes more combat-oriented, the need for a larger full-time organization becomes greater. Hence, as the insurgency grows, the insurgent group becomes more and more dependent on taxation of the local population for survival.

The government group has some advantage in the area of taxation in that it does not have to tax exclusively in the area (or areas) in which the insurgents are located. The government may even tax those areas of the country under firm control more heavily, thereby relieving the contested areas. On the other hand, the government must recruit combat troops directly from the population.

Ultimately, the effect of taxation of money and food and/or the recruitment of manpower away from the population is to reduce the civilian standard of living. Historically, contested areas in insurgency situations have been ones of a low standard of living. Undoubtedly there exists a point at which one or both sides begin to pay a penalty for taxation and recruitment in their psychological efforts. If an analyst were able to gain some insight into what constitutes a perceptible change in the standard of living in terms of money, food and manpower removel from a given beginning standard, he could include this factor as a negative influence on both sides' propaganda efforts. Experiments could then be conducted using various government recruitment and taxation policies. For example, one might attempt to determine the net effect on the system of a governmental policy of removing enough food from the contested area population to reduce them to subsistance living, thereby denying supplies to the insurgents. It is not clear what the benefits and dangers of such a policy are. If carefully researched and constructed, this taxation and recruitment submodel could be a most rewarding addition to the insurgency growth model.

This insurgency model and the accompanying computer simulation were developed to provide a basis from which others could, through additional research, formulate an analytical tool for use by government planners and analysts in the course of dealing with the seemingly ever-present problem of insurgency. It is hoped that the suggestions for further research contained in this chapter will encourage a continuation of the effort to produce a practicable insurgency growth model.

APPENDIX

The following computer program was written in DYNAMO II for the IBM 360-67 computer. The program was employed as an insurgency growth simulation in this study.

```
*      INSURGENCY GROWTH MODEL
NOTE
NOTE   BEGIN POPULATION EQUATIONS
NOTE
N PT=10000 TOTAL POPULATION
N INS=INSC INSURGENT POPULATION
N GC=GCC GOVERNMENT POPULATION
C INSC=100
C GCC=3000
N PIPRE=PIT INS. PROPAGANDA LAST DT
N PGPRE=PGT GOVT. PROPAGANDA LAST DT
N NC=PT-INS-GC INITIAL NEUTRAL POPULATION
N GCL=GC
N INSL=INS
L GCL.K=GC.J
A GINC.K=(GC.K-GCL.K)/GCL.K
L INSL.K=INS.J
A IINC.K=(INS.K-INSL.K)/INSL.K
L INS.K=INS.J+DT*(IGR.JK-IAR.JK) INS. POP. LEVEL
R IGR.KL=PMNI.K*NC.K*NCSAF.K+PMGI.K*GC.K INS. POP. GEN. RTE.
R IAR.KL=(PMIN.K+PMIG.K)*INS.K+DI.K INS. POP. ATTRITION RATE
L GC.K=GC.J+DT*(GGR.JK-GAR.JK) GOVT. POP. LEVEL
R GGR.KL=PMNG.K*NC.K*NCSAF.K+PMIG.K*INS.K GOVT. POP. GEN.
R GAR.KL=(PMGN.K+PMGI.K)*GC.K+POLF.K*PG.K GOVT. POP. ATTR.
L NC.K=NC.J+DT*(NCGR.JK-NCAR.JK) NEUTRAL POPULATION LEVEL
R NCGR.KL=PMIN.K*INS.K+PMGN.K*GC.K NEUTRAL POP. GENERATION
R NCAR.KL=PMNI.K*NC.K+PMNG.K*NC.K NEUTRAL POP. ATTRITION
A NCSAF.K=FIFGE(ONE,ZERO,NC.K,ZERO) DUMMY
NOTE
NOTE   BEGIN PROPAGANDA EQUATIONS
NOTE
A IWIN.K=(PMNI.K*NC.K+PMGI.K*GC.K+PMGN.K*GC.K)/PI.K
C ZERO=0
C ONE=1
C ALPHAI=.1 CONSTANT FOR EXP. SMOOTHING, INS.
N MALPHAI=ONE-ALPHAI
C ALPHAG=.1 CONSTANT FOR EXP. SMOOTHING, GOVT.
N MALPHAG=ONE-ALPHAG
NOTE   BEGIN INS. PROPAGANDA EQUATIONS
NOTE
L PIPRE.K=PI.J INS. POP. PREV. DT
A PI.K=ALPHAI*PIT.K+MALPHAI*PIPRE.K INS. PROPAGANDA
A PIT.K=TABLE(TPIT,GCRI.K,0,1,.1) INS. PROP.
T TPIT=0,.1,.5,1.5,6,8.8,10,9,5.5,2.5,0 TABLE FOR INS. PROP.
A GCRI.K=IMI.K*(GC.K/PT.K)+GC.K/PT.K INS. EST. OF GOVT. POP.
A IMI.K=NOISE()/5 INS. INTELLIGENCE MULTIPLIER
NOTE
NOTE   PROBABILITY MULTIPLIERS FROM INS. PROPAGANDA
NOTE
A PMNI.K=PRI.K*NCR.K*PFNI.K PROB. NEUTRAL-TO-INS.
A PRI.K=TABLE(TPRI,PI.K,0,10,1) PROB. INS. PROP. REACHES
T TPRI=0,.02,.05,.09,.17,.4,.58,.7,.75,.79,.8 TABLE FOR PRI
A NCR.K=NC.K/PT.K NEUTRAL-TO-TOTAL POP. RATIO
A PFNI.K=TABLE(TPFNI,PI.K,0,10,1) PROB. INS. PROP. FAV. NC
T TPFNI=0,.12,.22,.3,.38,.41,.46,.48,.49,.49,.5 TABLE PFNI
NOTE
A PMGI.K=PRI.K*GCR.K*PFGI.K PROB. GOVT.-TO-INS.
A GCR.K=GC.K/PT.K GOVT.-TO-TOTAL POP. RATIO
```

```
A PFGI.K=TABLE(TPFGI,PI.K,0,10,2) PROB. GC GOES INS.
T TPFGI=0,.05,.1,.16,.18,.19 TABLE FOR PFGI
NOTE
A PMGN.K=PRI.K*GCR.K*PFGN.K PROB. GOVT.-TO-NEUTRAL
A PFGN.K=TABLE(TPFGN,PI.K,0,10,2) PROB. GC GOES NEUTRAL
T TPFGN=0,.1,.2,.28,.34,.35 TABLE FOR PFGN
NOTE
NOTE   BEGIN GOVT. PROPAGANDA EQUATIONS
NOTE
A GWIN.K=(PMIN.K*INS.K+PMIG.K*INS.K+PMNG.K*NC.K)/PG.K
L PGPRE.K=PG.J PREVIOUS GOVT. PROP.
A PG.K=ALPHAG*PGT.K+MALPHAG*PGPRE.K PRESENT GOVT. PROP.
A PGT.K=TABLE(TPGT,GCRG.K,0,1,.1) GOVT. PROP. REQUIRED
T TPGT=0,1,3,5,9,10,9,5,3,1,0 TABLE FOR PGT
A GCRG.K=IMG.K*(GC.K/PT.K)+GC.K/PT.K GOVT. EST. OF RATIO
A IMG.K=NOISE()/2.5 GOVT. INTELLIGENCE MULTIPLIER
NOTE
NOTE   PROBABILITY MULTIPLIERS FROM GOVT. PROPAGANDA
NOTE
A PMIN.K=PRG.K*IR.K*PFIN.K PROB. INS.-TO-NEUTRAL
A PRG.K=TABLE(TPRG,PG.K,0,10,1) PROB. GOVT. PROP. REACHES
T TPRG=0,.02,.05,.09,.13,.26,.6,.85,.92,.97,1 TABLE FOR PRG
A IR.K=INS.K/PT.K ACTUAL INS.-TO-TOTAL POP. RATIO
A PFIN.K=TABLE(TPFIN,PG.K,0,10,2) PROB. INS. GOES NEUTRAL
T TPFIN=0,.03,.06,.15,.23,.26 TABLE FOR PFIN
NOTE
A PMIG.K=PRG.K*IR.K*PFIG.K PROB. INS.-TO-GOVT.
A PFIG.K=TABLE(TPFIG,PG.K,0,10,2) PROB. INS. GOES GOVT.
T TPFIG=0,.08,.12,.16,.18,.19 TABLE FOR PFIG
NOTE
A PMNG.K=PRG.K*NCR.K*PFNG.K PROB. NEUTRAL-TO-GOVT.
A PFNG.K=TABLE(TPFNG,PG.K,0,10,2) PROB. NEUTRAL GOES GOVT.
T TPFNG=0,.05,.1,.25,.37,.39 TABLE FOR PFNG
NOTE      MILITARY SEGMENT
C MULT=4
C THOU=1000
C PER=.05
C DEL=2
C DELP=3
C HUN=100
N TGPTEP=ZERO
N IDEAD=ZERO
N GDEAD=ZERO
N TI=PINS*INS INITIAL INS. TROOPS
N TGP=PER*PT INITIAL GOVT. POLICE
N TGR=TG-TGP INITIAL GOVT. REGULARS
N TG=TMG
A KILLR.K=DG.K/DI.K
L GDEAD.K=GDEAD.J+TGPAR.JK+TGRAR.JK TOTAL GOVT. TROOPS DEAD
L IDEAD.K=IDEAD.J+TIAR.JK TOTAL INS. TROOPS DEAD
L TG.K=TG.J+DT*(TGGR.JK-TGAR.JK) GOVT. TROOPS LEVEL
R TGGR.KL=TGADD.K GOVT. TROOP GENERATION RATE
R TGAR.KL=TGSUB.K+DG.K GOVT. TROOP ATTRITION RATE
L TGP.K=TGP.J+DT*(TGPGR.JK-TGPAR.JK) GOVT. POLICE LEVEL
R TGPGR.KL=TGPADD.K POLICE GENERATION RATE
R TGPAR.KL=POLF.K*DG.K POLICE ATTRITION RATE
L TGR.K=TGR.J+DT*(TGRGR.JK-TGRAR.JK) GOVT. REGULAR TROOPS
R TGRGR.KL=TGRADD.K REGULAR GENERATION RATE
```

```
R TGRAR.KL=TGRSUB.K+REGF.K*DG.K REGULAR ATTRITION RATE
L TI.K=TI.J+DT*(TIGR.JK-TIAR.JK) INS. TROOP LEVEL
R TIGR.KL=PINS.K*INS.K-TI.K INS. TROOP GENERATION RATE
R TIAR.KL=DI.K INS. TROOP ATTRITION RATE
L PT.K=PT.J-DT*(TIAR.JK+TGPAR.JK) TOTAL POP. LEVEL
NOTE
NOTE
A REGF.K=TGR.K/TGTOT.K REGULAR-TO-TOTAL GOVT. TROOPS RATIO
A POLF.K=ONE-REGF.K POLICE-TO-TOTAL GOVT. TROOPS RATIO
A INSR.K=INS.K/PT.K INS.-TO-TOTAL POP. RATIO
A PINS.K=TABLE(TPINS,INSR.K,0,1,.1) PERCENT OF INS.
T TPINS=0,.15,.33,.45,.58,.7,.67,.6,.45,.4,.4 TABLE PINS
A TIEST.K=TI.K+IMC.K*TI.K GOVT. EST. OF INS.TROOPS
A TMG.K=TABLE(TTMG,TIEST.K,0,5000,1000) GOVT. TROOPS REQ.
T TTMG=1000,1000,2000,3000,4000,5000 TABLE FOR TMG
A TGDIF.K=TMG.K-TG.K PRESENT GOVT. TROOP REQUIREMENT
A TGDIFP.K=-TGDIF.K
A TGADD.K=FIFGE(TGDIF.K,ZERO,TGDIF.K,ZERO) GOVT. ADD
A TGSUB.K=FIFGE(ZERO,TGDIFP.K,TGDIF.K,ZERO) GOVT. REMO.
A FCI.K=TABLE(TFCI,TI.K,0,5000,1000) FIGHTING CONSTANT INS
T TFCI=.1,.1,.125,.15,.175,.2 TABLE FOR FCI
A FCG.K=TABLE(TFCG,TI.K,0,5000,1000) FIGHTING CONSTANT GOV
T TFCG=.00005,.00005,.00015,.0002,.0002,.0002 TABLE FOR FCG
A EENC.K=TABLE(TEENC,TI.K,0,5000,1000) EXP. NO. ENG.
T TEENC=1,1,15,25,30,30 TABLE FOR EENC
A AFSG.K=FIFGE(FST.K,TG.K,TI.K,THOU) AVERAGE FORCE GOVT.
A AFSI.K=FIFGE(FST.K,TI.K,TI.K,THOU) AVERAGE FORCE INS.
A FST.K=TABLE(TFST,TI.K,0,5000,1000) FORCE SIZE
T TFST=0,50,100,200,300,500 TABLE FOR FST
A TTG.K=EENC.K*AFSG.K TOTAL GOVT. TROOPS INVOLVED
A TTI.K=EENC.K*AFSI.K TOTAL INS. TROOPS INVOLVED
A IC.K=FIFGE(THOU,TTI.K,TI.K,THOU) CONSTANT FOR COMBAT EQN.
A DG.K=FCI.K*TTI.K GOVT. TROOPS KILLED
A DI.K=FCG.K*TTG.K*IC.K INS. TROOPS KILLED
L TGPTEP.K=TGPTEM.J
A TGPACT.K=FIFGE(TGPTEM.K,TGPTEP.K,TGPTEM.K,TGPTEP.K)
A TGPDES.K=MULT*(TGPACT.K-TGPTEP.K)
A TGPTEM.K=FIFGE(TGPDIF.K,ZERO,TGPDIF.K,ZERO) POLICE DES.
A TGPDIF.K=PER*PT.K-TGP.K POLICE REQUIRED
A TGPADD.K=DELAY1(TGPDES.K,DEL)  DELAY FOR ADDITION OF POL.
A TGRDIF.K=TMG.K-TGP.K-TGR.K REGULARS REQUIRED
A TGRDES.K=FIFGE(TGRDIF.K,ZERO,TGRDIF.K,ZERO) REGULARS DES.
A LOTS.K=FIFGE(ZERO,ABSDIF.K,TGRDIF.K,ZERO) REGULARS EXC.
A ABSDIF.K=-TGRDIF.K
A REML.K=FIFGE(LOTS.K,ZERO,LOTS.K,HUN) REMOVE ANY?
A TGRSUBT.K=DELAY1(REML.K,DELP) DELAY FOR REGULAR REMOVAL
A TGRADDT.K=DELAY1(TGRDES.K,DELP) DELAY FOR REGULARS ADDED
A TGRADD.K=FIFGE(TGRADDT.K,ZERO,TGRDIF.K,ZERO)
A TGRSUB.K=FIFGE(ZERO,TGRSUBT.K,TGRDIF.K,ZERO)
A TGTOT.K=TGR.K+TGP.K TOTAL GOVT. TROOPS
NOTE
NOTE
PLOT TMG=*,TGTOT=G,TI=I
SPEC DT=1/LENGTH=60/PRTPER=1/PLTPER=1
RUN
```

SELECT BIBLIOGRAPHY

1. Barrett, E. A., Lindsay, G. F., Read, R. R., Some Aspects of the Current Insurgency and Counterinsurgency Efforts in Thailand, Naval Postgraduate School paper, 1967.

2. Brown, Robert G., Statistical Forecasting for Inventory Control, McGraw-Hill Book Company, Inc., 1959.

3. Deichman, S. J., "A Lanchester Model of Guerrilla Warfare," Operations Research, November-December 1962.

4. Forrester, Jay W., Principles of Systems, Wright-Allen Press Inc., 1968.

5. Pugh, Alexander L. III, DYNAMO II User's Manual, The MIT Press, 1970.

6. Simonsen, R. L., Proposed Measure of Effectiveness for Counterinsurgency Operations, M. S. Thesis, Naval Postgraduate School, Monterey, California, June, 1967.

7. Sullivan, Edward F., Methods for Estimating Present and Future Insurgent Strength, M. S. Thesis, Naval Postgraduate School, Monterey, California, October, 1969.

8. Defense Research Corp. Report TM-353, The Feasibility of Applying War Gaming and Computer Simulation to Counterinsurgency, by B. Fitzgerald, et. al., April, 1966.

9. Research Analysis Corp., Guidelines for Measuring Success in Counter-Insurgency, by S. N. Bjelajac.

10. Research Analysis Corp. TP-163 (C), Concept of Insurgency Conflict, by Dorthy K. Clark, et. al., July, 1965.

11. Research Analysis Corp. Field Paper 20, Insurgent Psychological Operations, Recruitment, and Training in Thailand, by Richard G. Sharp, January, 1969.

12. RAND Corp. RM-5239-ISA/ARPA, Insurgent Organization and Operations: A Case Study of the V. C. in the Delta, by M. Anderson, et. al., August, 1967.

13. RAND Corp. RM-6358/PR, Predicting Insurgent and Government Decisions: The Power Bloc Model, by W. M. Jones, December, 1970.

14. RAND Corp. Report 3 P-2642, Notes on Non-military Measures in Control of Insurgency, by Guy J. Pauker, October, 1962.

15. RAND Corp. RM-5500-ARPA, The Insurgent Environment, by Michael R. Pearce, May 1969.

16. RAND Corp. P-1840, The Role of Operations Research in Planning for Limited War, by M. G. Weiner, May 1960.

17. Stanford Research Institute RSSC-RM 4923-30, Counterinsurgency Organizations and Programs: South Thailand, by Robert E. Morse, March 1969.

18. Stanford Research Institute Report 67-2000, The Malayan Communist Youth League: A Case Study of Communist Population Control in Southern Thailand, by F. M. Osanka, January 1967.

19. Stanford Research Institute Report 67-1422, The Communist Terrorist Organization in Southern Thailand, by D. A. Price, January 1967.

20. Stanford Research Institute RSSC-RM 4923-11, An Analytic Approach to the Estimation of Counterguerrilla Capabilities, by R. F. Rhyne, September 1968.

21. Stanford Research Institute Report 66-4160, Selected Documents Describing the Communist Terrorist Organization in Southern Thailand, by D. E. Seeley, September 1966.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Associate Professor G. F. Lindsay, Code 55Ls Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
4.	Associate Professor A. F. Andrus, Code 55As Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
5.	Asst. Prof. A. M. Shorb, Code 53Sp Department of Mathematics Naval Postgraduate School Monterey, California 93940	1
6.	LT Robert M. Combs, USN Naval Destroyer School Newport, Rhode Island	1
7.	Department of Operations Research and Administrative Sciences, Code 55 Naval Postgraduate School Monterey, California 93940	1
8.	Chief of Naval Personnel PERS 116 Department of the Navy Washington, D. C. 20370	1

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN INSURGENCY GROWTH MODEL		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1973 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Robert Meredith Combs		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE September 1973 13. NUMBER OF PAGES 85
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

INSURGENCY; COUNTERINSURGENCY; GUERRILLA WARFARE; SYSTEM DYNAMICS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A generalized conception of an insurgency situation is examined with a systems approach. The model is divided into two sectors, propaganda and military. The emphasis in the propaganda sector is on all actions taken by the insurgent and government sides which have a pschological impact on the population. In the military sector variables associated with combat and troop replacement are examined. A computer simulation, written

20. in DYNAMO II, is provided and several simulation runs are examined. Suggestions for further research are also included.